FOR THE INCREASE AND DIFFUSION OF KNOWLEDGE AMONG MEN

PER ORBEM

SMITHSONIAN INSTITUTION WASHINGTON 1846

ANNUAL REPORT OF THE BOARD OF REGENTS OF
THE SMITHSONIAN INSTITUTION

SHOWING THE

OPERATIONS, EXPENDITURES, AND CONDITION OF THE INSTITUTION FOR THE YEAR ENDING JUNE 30

1927

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LETTER

FROM THE

ACTING SECRETARY OF THE SMITHSONIAN INSTITUTION

SUBMITTING

THE ANNUAL REPORT OF THE BOARD OF REGENTS OF THE INSTITUTION FOR THE YEAR ENDING JUNE 30, 1927

SMITHSONIAN INSTITUTION,
Washington, November 26, 1927.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year ending June 30, 1927. I have the honor to be,

Very respectfully, your obedient servant,

C. G. ABBOT,
Acting Secretary.

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2. Report of the executive committee of the Board of Regents, exhibiting the financial affairs of the Institution, including a statement of the Smithsonian fund, and receipts and expenditures for the year ending June 30, 1927.

3. Proceedings of the Board of Regents for the fiscal year ending June 30, 1927.

4. General appendix, comprising a selection of miscellaneous memoirs of interest to collaborators and correspondents of the Institution, teachers, and others engaged in the promotion of knowledge. These memoirs relate chiefly to the calendar year 1927.

THE SMITHSONIAN INSTITUTION

June 30, 1927

Presiding officer ex officio.—CALVIN COOLIDGE, President of the United States.
Chancellor.—WILLIAM HOWARD TAFT, Chief Justice of the United States.
Members of the Institution:

CALVIN COOLIDGE, President of the United States.
CHARLES G. DAWES, Vice President of the United States.
WILLIAM HOWARD TAFT, Chief Justice of the United States.
FRANK B. KELLOGG, Secretary of State.
ANDREW W. MELLON, Secretary of the Treasury.
DWIGHT FILLEY DAVIS, Secretary of War.
JOHN G. SARGENT, Attorney General.
HARRY S. NEW, Postmaster General.
CURTIS D. WILBUR, Secretary of the Navy.
HUBERT WORK, Secretary of the Interior.
WILLIAM M. JARDINE, Secretary of Agriculture.
HERBERT CLARK HOOVER, Secretary of Commerce.
JAMES JOHN DAVIS, Secretary of Labor.

Regents of the Institution:

WILLIAM HOWARD TAFT, Chief Justice of the United States, Chancellor.
CHARLES G. DAWES, Vice President of the United States.
REED SMOOT, Member of the Senate.
WOODBRIDGE N. FERRIS, Member of the Senate.
JOSEPH T. ROBINSON, Member of the Senate.
ALBERT JOHNSON, Member of the House of Representatives.
R. WALTON MOORE, Member of the House of Representatives.
WALTER H. NEWTON, Member of the House of Representatives.
CHARLES F. CHOATE, Jr., citizen of Massachusetts.
HENRY WHITE, citizen of Washington, D. C.
ROBERT S. BROOKINGS, citizen of Missouri.
IRWIN B. LAUGHLIN, citizen of Pennsylvania.
FREDERIC A. DELANO, citizen of Washington, D. C.
DWIGHT W. MORROW, citizen of New Jersey.

Executive committee.—HENRY WHITE, FREDERIC A. DELANO, R. WALTON MOORE.
Acting Secretary.—C. G. ABBOT.
Assistant Secretary.—ALEXANDER WETMORE.
Chief Clerk.—HARRY W. DORSEY.
Accounting and disbursing agent.—N. W. DORSEY.
Editor.—W. P. TRUE.
Librarian.—WILLIAM L. CORBIN.
Appointment clerk.—JAMES G. TRAYLOR.
Property clerk.—J. H. HILL.

NATIONAL MUSEUM

Assistant Secretary (in charge).—ALEXANDER WETMORE.
Administrative assistant to the Secretary.—W. DE C. RAVENEL.
Head curators.—WALTER HOUGH, LEONHARD STEJNEGER, GEORGE P. MERRILL.
Curators.—PAUL BARTSCH, R. S. BASSLER, T. T. BELOTE, AUSTIN H. CLARK, F. W. CLARKE, F. V. COVILLE, CHARLES W. GILMORE, WALTER HOUGH, L. O. HOWARD, ALEŠ HRDLIČKA, NEIL M. JUDD, H. W. KRIEGER, FREDERICK L. LEWTON, GEORGE P. MERRILL, GERRIT S. MILLER, Jr., CARL W. MITMAN, ROBERT RIDGWAY, WALDO L. SCHMITT, LEONHARD STEJNEGER.
Associate curators.—J. M. ALDRICH, W. R. MAXON, CHARLES E. RESSER, CHARLES W. RICHMOND, J. N. ROSE, PAUL C. STANDLEY, DAVID WHITE.
Chief of correspondence and documents.—H. S. BRYANT.
Disbursing agent.—N. W. DORSEY.
Superintendent of buildings and labor.—J. S. GOLDSMITH.
Editor.—MARCUS BENJAMIN.
Assistant Librarian.—ISABEL L. TOWNER.
Photographer.—ARTHUR J. OLMSTED.
Property clerk.—W. A. KNOWLES.
Engineer.—C. R. DENMARK.
Shipper.—L. E. PERRY.

NATIONAL GALLERY OF ART

Director.—WILLIAM H. HOLMES.

FREER GALLERY OF ART

Curator.—JOHN ELLERTON LODGE.
Associate curator.—CARL WHITING BISHOP.
Assistant curator.—GRACE DUNHAM GUEST.
Associate.—KATHARINE NASH RHOADES.
Superintendent.—JOHN BUNDY.

BUREAU OF AMERICAN ETHNOLOGY

Chief.—J. WALTER FEWKES.
Ethnologists.—JOHN P. HARRINGTON, J. N. B. HEWITT, FRANCIS LA FLESCHE, TRUMAN MICHELSON, JOHN R. SWANTON.
Archeologist.—F. H. H. ROBERTS, Jr.
Editor.—STANLEY SEARLES.
Librarian.—ELLA LEARY.
Illustrator.—DE LANCEY GILL.

INTERNATIONAL EXCHANGES

Acting secretary (in charge).—C. G. ABBOT.
Chief clerk.—C. W. SHOEMAKER.

NATIONAL ZOOLOGICAL PARK

Director.—WILLIAM M. MANN.
Assistant director.—A. B. BAKER.

ASTROPHYSICAL OBSERVATORY

Director.—C. G. ABBOT.
Research assistant.—F. E. FOWLE, Jr.
Research assistant.—L. B. ALDRICH.

REGIONAL BUREAU FOR THE UNITED STATES, INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE

Assistant in charge.—LEONARD C. GUNNELL.

REPORT

OF THE

ACTING SECRETARY OF THE SMITHSONIAN INSTITUTION

C. G. Abbot

FOR THE YEAR ENDING JUNE 30, 1927

To the Board of Regents of the Smithsonian Institution:

Gentlemen: I have the honor to submit herewith my report showing the activities and condition of the Smithsonian Institution and the Government bureaus under its administrative charge during the fiscal year ended June 30, 1927. The first 34 pages contain a summary account of the affairs of the Institution. Appendixes 1 to 10 give more detailed reports of the operations of the United States National Museum, the National Gallery of Art, the Freer Gallery of Art, the Bureau of American Ethnology, the International Exchanges, the National Zoological Park, the Astrophysical Observatory, the United States Regional Bureau of the International Catalogue of Scientific Literature, the Smithsonian library, and of the publications issued under the direction of the Institution.

THE SMITHSONIAN INSTITUTION

THE ESTABLISHMENT

The Smithsonian Institution was created by act of Congress in 1846, according to the terms of the will of James Smithson, of England, who in 1826 bequeathed his property to the United States of America, "to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men." In receiving the property and accepting the trust, Congress determined that the Federal Government was without authority to administer the trust directly, and therefore constituted an "establishment" whose statutory members are "the President, the Vice President, the Chief Justice, and the heads of the executive departments."

THE BOARD OF REGENTS

The affairs of the Institution are administered by a Board of Regents whose membership consists of "the Vice President, the Chief Justice, three Members of the Senate, and three Members of

the House of Representatives, together with six other persons other than Members of Congress, two of whom shall be resident in the city of Washington, and the other four shall be inhabitants of some State, but no two of them of the same State." One of the regents is elected chancellor by the board; in the past the selection has fallen upon the Vice President or the Chief Justice; and a suitable person is chosen by the regents as secretary of the Institution, who is also secretary of the Board of Regents and the executive officer directly in charge of the Institution's activities.

The following changes occurred in the personnel of the board during the year: The term as a regent of Senator George Wharton Pepper expired upon his retirement as a Member of the Senate on March 3, 1927, and Senator Joseph T. Robinson was appointed by the Vice President to succeed him on March 4, 1927. Senator Reed Smoot was reappointed a regent by the Vice President on March 4, 1927.

The roll of the regents at the close of the fiscal year was as follows: William H. Taft, Chief Justice of the United States, chancellor; Charles G. Dawes, Vice President of the United States; members from the Senate, Reed Smoot, Woodbridge N. Ferris, Joseph T. Robinson; members from the House of Representatives, Albert Johnson, R. Walton Moore, Walter H. Newton; citizen members, Charles F. Choate, jr., Massachusetts; Henry White, Washington, D. C.; Robert S. Brookings, Missouri; Irwin B. Laughlin, Pennsylvania; Frederic A. Delano, Washington, D. C.; and Dwight W. Morrow, New Jersey.

GENERAL CONSIDERATIONS

Death of Secretary Walcott.—On February 9, 1927, the fourth secretary of the Smithsonian Institution, Charles Doolittle Walcott, passed from us. For 20 years Doctor Walcott had successfully guided the destiny of the Smithsonian, and his death is a severe blow to the Institution and a great bereavement to his friends and associates on the staff. This report is not the place to review in detail the life and work of Doctor Walcott—that will be done later in a biography to be published in the general appendix to the Annual Report of the Board of Regents.

It has been my privilege to be closely associated with Doctor Walcott during the entire 20 years of his administration. He took a genuine kindly interest in his associates, rejoiced without any gesture of appropriation in their successes and the growth of their reputations, and sorrowed in their disappointments and troubles. From his long life of affairs he was always ready to quote wise or illustrative passages, so that his counsel was most helpful and sagacious. He was highly approachable, even in temper, and exceed-

ingly simple in all his habits. For many years he occupied a leading place in the business of his church, and he had a strong untroubled religious faith, crowned by full confidence in a future life.

Of commanding height and noble features, he was physically every inch a worthy head of the Institution. A strong and experienced administrator, of indefatigable industry, he was able not only to shape its administration but to carry on at the same time his own world-renowned researches in geology and paleontology. It has been said that 70 per cent of existing knowledge of Cambrian and Pre-Cambrian paleontology is due to him, and of this one-half was acquired by him while secretary of the Smithsonian Institution.

The late secretary was a man of the widest interests. He was prominently in public life in Washington for many years before coming to the Smithsonian, having served as director of the United States Geological Survey. At that time, also, he secured the passage of a law organizing the forest surveys of the country, and organized and directed for five years the United States Reclamation Service.

He took a leading part in the affairs of the Carnegie Institution of Washington, which he had been largely instrumental in founding, and also a leading rôle in the promotion and encouragement of the new science of aeronautics, culminating during the World War in his appointment by President Wilson as a member of the National Advisory Committee for Aeronautics. During the war he served as chairman of its executive committee and later as chairman of the committee itself until his death. He was prominent in the National Research Council, for several years president of the National Academy of Sciences, and president of other scientific societies of national scope.

One of the most important steps taken by Secretary Walcott in the last years of his administration was the approval of a definite campaign to increase the endowment funds of the Institution. This project is mentioned in his last two annual reports, that for 1926 outlining the preliminary steps taken. Although the matter has perhaps moved more slowly than anticipated, nevertheless very definite progress has been made, and there is real promise of a successful outcome of the project. Doctor Walcott, like Secretary Langley before him, regarded the totally inadequate income of the Institution for research and publication as presenting a crisis in its affairs, and it is earnestly hoped that plans for increasing that income, so vital to the future work and reputation of the Institution, may be carried on successfully.

Gifts.—Four especially noteworthy gifts and bequests came to the Institution during the past year—the Canfield mineralogical collection, the Roebling mineralogical collection, the John Donnell Smith

herbarium and botanical library, and the Canu collection of French Cenozoic and Mesozoic fossils, exceeding 100,000 specimens. The Canfield collection of minerals came as a bequest from Dr. Frederick A. Canfield, of New Jersey. It contains some 9,000 minerals, many of them unique and all of exceptional quality, and to insure its continued development Doctor Canfield also bequeathed to the Institution the sum of $50,000, the income from which is to be used for that purpose. The Roebling mineralogical collection was presented to the Smithsonian by Mr. John A. Roebling, of Bernardsville, N. J., in memory of his father, Col. Washington A. Roebling, who died in July, 1926, willing the mineral collection to his son. The Roebling collection contains over 16,000 specimens, including practically every known mineral species. Mr. Roebling also accompanied his gift with an endowment fund of $150,000 for its development. The John Donnell Smith herbarium and botanical library form the most munificent gift of botanical material ever received by the National Herbarium. The Smith herbarium, containing well over 100,000 specimens, all well preserved and excellently mounted, is particularly rich in Central American material, with numerous type specimens of species described by Captain Smith in his own extensive botanical researches on the flora of that region.

Under the terms of the will of the late Catherine Walden Myer, and by an agreement with the other legatees named in the will, the Institution has received in cash the sum of $3,649.91 and notes secured by certain property in Washington amounting to $14,618. The will stipulated that the income from this bequest should be used for the purchase of works of art for use and benefit of the National Gallery of Art.

FINANCES

The permanent investments of the Institution consist of the following:

Total endowment for general or specific purposes (exclusive of Freer funds)	$1,385,279.75
Of this total there is deposited in the Treasury of the United States as provided by law	1,000,000.00
Deposited in the consolidated fund:	
Miscellaneous securities, etc., either purchased or acquired by gift; cost or value at date acquired	373,759.75
Charles D. and Mary Vaux Walcott research fund, stock (gift); value	11,520.00

The sums invested for each specific fund or securities, etc., acquired by gift are described as follows:

Fund	United States Treasury	Consolidated fund	Walcott research fund	Total
Avery fund	$14,000.00	$40,456.46		$54,456.46
Virginia Purdy Bacon fund		62,272.93		62,272.93
Lucy H. Baird fund		1,728.09		1,728.09
Chamberlain fund		35,000.00		35,000.00
Habel fund	500.00			500.00
Hamilton fund	2,500.00	500.00		3,000.00
Caroline Henry fund		1,223.33		1,223.33
Hodgkins fund:				
General	116,000.00	37,275.00		153,275.00
Specific	100,000.00			100,000.00
Bruce Hughes fund		14,158.90		14,158.90
Lucy T. and George W. Poore fund	26,670.00	21,296.42		47,966.42
Addison T. Reid fund	11,000.00	7,299.16		18,299.16
Rhees fund	590.00	357.34		947.34
Roebling fund		150,000.00		150,000.00
George H. Sanford fund	1,100.00	675.72		1,775.72
Smithson fund	727,640.00	1,516.40		729,156.40
Charles D. and Mary Vaux Walcott research fund			$11,520.00	11,520.00
Total	1,000,000.00	373,759.75	11,520.00	1,385,279.75

The Institution gratefully acknowledges gifts from the following donors:

Dr. W. L. Abbott, for collecting expedition to Haiti and Santo Domingo.

Mrs. Laura Welsh Casey, further funds for expenses in connection with Casey collection of Coleoptera.

Mr. Walter Chrysler, further funds for expedition to Africa to collect animals for National Zoological Park.

Mr. Childs Frick, for explorations in vertebrate paleontology.

National Academy of Sciences, for paleontological researches.

Mrs. Cornelia Livingston Pell, for care of Pell collection.

Mr. John A. Roebling, for the establishment of the Roebling fund for care of Roebling collection of minerals, and for other purposes.

Mr. Homer E. Sargent, for manuscript on Salish basketry.

Dr. Frank Springer, further funds for publication of volume "American Silurian Crinoids," and for other purposes.

Mr. Chas. T. Simpson, for work on West Indian shells.

Mr. H. B. Swales, for purchase of specimens, etc.

The Institution has also received contributions from the following friends for the funds as listed below

Endowment campaign expense fund: Mr. Frederic A. Delano, Mr. Dwight W. Morrow, Mrs. Mary Vaux Walcott.

Endowment fund: Mr. John Baker, Mr. W. C. Condon, the Gould Co., Mr. J. Frank Haan, Mr. Paul Hartley, Mr. S. M. Henrie, Mr. George A. Knapp, Mr. W. C. Rogers, Mr. H. Seddon, and Mr. Hans Wilkens.

The Institution also received from the estate of Catherine Walden Myer the sum of $3,649.91, a payment on account of a bequest for purchase of works of art for use and benefit of the National Gallery of Art.

Freer Gallery of Art.—The invested funds of the Freer bequest are classified as follows:[1]

Court and grounds fund	$365,441.13
Court and grounds, maintenance fund	78,953.36
Curator fund	316,830.25
Residuary legacy	3,410,655.87
Total	4,171,880.61

The practice of depositing on time in local trust companies and banks such revenues as may be spared temporarily has been continued during the past year, and interest on these deposits has amounted to $3,813.38. The income during the year for current expenses, consisting of interest on permanent investments and other miscellaneous sources, amounted to $65,392.21. Revenues and principal of funds for specific purposes, except the Freer bequest, amounted to $320,977.75. Revenues on account of Freer bequest amounted to $249,737.84; amount received from sale of stocks and bonds, $1,152,735.58; aggregating a total of $1,788,843.38.

The disbursements, described more fully in the annual report of the executive committee, were classed as follows: General objects of the Institution, $57,518.69; for specific purposes (except the Freer bequest), $305,220.90; and investments and expenditures pertaining to Charles L. Freer bequest, $1,358,165.70. The total of balances on hand June 30, 1927, from all funds and mainly bearing interest on deposit, was $202,827.49.

The following appropriations were made by Congress for the Government bureaus under the administrative charge of the Smithsonian Institution for the fiscal year 1927:

International Exchanges		$46,260
American Ethnology		57,160
International Catalogue of Scientific Literature		7,500
Astrophysical Observatory		31,180
Additional assistant secretary		6,000
National Museum:		
Furniture and fixtures	$23,730	
Heating and lighting	78,140	
Preservation of collections	450,000	
Building repairs	12,000	
Books	1,500	
Postage	450	
		565,820
National Gallery of Art		29,381
National Zoological Park		173,199
Printing and binding		90,000
Total		1,006,500

[1] The sinking fund has been discontinued and each fund credited with its portion of same.

EXPLORATIONS AND FIELD WORK

More than 30 field expeditions, in which the Smithsonian Institution took a leading part, went out during the past year. The record is doubly interesting, in view of the fact that almost no unrestricted funds for field work were available, each expedition being separately financed either by the generosity of some friend of the Institution or through a cooperative arrangement with some other organization whereby the costs and collections were shared. Such a program of field work is of necessity more or less haphazard, since each opportunity presented must be grasped whether or not it fulfills the exact objects most valuable to the Institution. The more desirable method, obviously, and the one that would be followed if the Institution had complete financial independence, would be to map out in advance the essential expeditions in accordance with a definite plan.

The year's field work covered such widespread territory that an enumeration of the countries visited will be of interest. Abroad, Smithsonian expeditions worked in South West Africa, East Africa, Sumatra, China, Alaska, Canada, Mexico, Guatemala, Costa Rica, Panama, Ecuador, Peru, Chile, Jamaica, Haiti, England, France, and Germany. In the United States, California, Arizona, and Florida led with three expeditions each; Washington and Louisiana followed with two each; and Montana, Wyoming, New Mexico, Mississippi, New York, and New Jersey were visited by one expedition each.

Brief extracts from accounts of only a few of the expeditions will be given here to indicate the nature of the work and its preliminary results. Accounts of other field work will be found in the reports on certain of the bureaus under administrative charge of the Institution, appended hereto, namely, the National Museum, the Bureau of American Ethnology, and the Astrophysical Observatory. The Institution also publishes each year an exploration pamphlet, giving an illustrated summary of them.

SMITHSONIAN-CHRYSLER EXPEDITION TO AFRICA

The outstanding expedition of the year in point of popular interest was the Smithsonian-Chrysler Expedition to Africa to collect live wild animals for the National Zoological Park, under Smithsonian direction. The expedition was financed by Mr. Walter P. Chrysler, automobile manufacturer, and headed by Dr. W. M. Mann, director of the National Zoological Park; the other members were Mr. Stephen Haweis, artist and naturalist; Mr. F. G. Carnochan, of New York; and Mr. Arthur Loveridge, of the Museum of Comparative Zoology at Cambridge. Mr. Charles Charlton was sent by the Pathé Review to make a motion-picture record of the expedition.

Leaving New York March 20, 1926, the party arrived in Dar-es-Salaam, Tanganyika Territory, East Africa, on May 5. A license to collect was received from the governor of the Territory and headquarters were established at Dodoma, 250 miles inland.

Collecting was successfully carried on for some months at various localities in the Territory, the animals being sent back to Dodoma to be held there until the close of the work. One of the chief desiderata was a young rhinoceros, and although adult specimens were numerous, no young were seen. In the Ja-aida swamp country, where Doctor Mann went on the search for these animals, the hunt proved rather exciting. Doctor Mann says:

Altogether we saw 22 rhinos. Our safari was charged once while on the march, and four times at night rhinos charged through our camp. But in all of these we failed to locate a single young specimen. Five different times we crawled into the scrub 30 or 40 feet from a rhino to see if it had young and were disappointed each time. One locates these rhinos, by the way, through the tick birds, which make a loud twittering at the approach of any suspicious object to the rhino on which they are clustered for the purpose of eating the ticks which are so abundant on its body. Theoretically they serve a useful purpose to the rhino by warning him of his enemies. Actually we found they were useful in leading us to where the rhino were lying, for we were attracted by the birds to each of the rhinos that we found.

The night charges are simply the result of the stupidity of the rhino. We camped usually in the vicinity of water holes, and when the nearsighted beast came to water late at night or early in the morning he would suddenly notice that there were fires and natives about. Whereupon he would put his head down and charge through in a straight line. On these occasions the natives have a frantic desire to get into the tents to be near the white men and the guns; the white men, on the other hand, have a frantic desire to get out of their tents, and the result is a collision at the entrance. Two rhinos came into our camp the same night.

At Tula, where the expedition next camped in the hope particularly of securing giraffes, animals were abundant.

Two native sultans, Chanzi and Chaduma, joined forces with us for a week, bringing with them about 500 natives. With the help of these we had the most successful trip of the expedition. Some of the boys from a mountain near by had had some experience in netting game. They make a coarse seine of native rope in sections about 5 feet high and 15 feet long. These were placed in a row, until they made about 1,000 feet of native fence, one boy hiding behind each section. The two lots of natives would double over their ends and join in a circle about a mile in circumference, then closing in toward the net. The object was to drive animals into the net, but nine times out of ten they would break through the line. Occasionally, however, they came straight on. One day a herd of over 50 impalla was surrounded. This is the most graceful antelope in Africa and a great leaper. Most of them sailed right over the net, but five fell short and we got them all. Fortune was with us as far as impalla were concerned, for it is one of the most delicate animals to handle, and yet all of ours reached Boston alive and in good condition.

Wart hogs were captured in the same way, and a troop of four were added to the collection.

Giraffes, however, proved to be very difficult to capture. A young one was finally separated from the herd and caught, but unfortunately died from pneumonia soon after. A pair was later obtained, however, from the Sudan Government. The expedition embarked from Dar-es-Salaam with about 1,700 live animals, nearly all of which were safely transported over the long journey to Washington.

This is by far the largest single collection ever brought to the National Zoological Park, and greatly increases the value and popular interest of the park's animal exhibits.

COLLECTING MICROFOSSILS IN EUROPE

Dr. R. S. Bassler, curator of paleontology in the National Museum, spent August and September, 1926, in collecting microfossils in France and Germany and in studying the geology of various classic localities in those countries. Microfossils have proved to be of the greatest value in the determination of underground geological structure, particularly in connection with the location of oil. The National Museum collections are rich in fossil micro-organisms from the American Mesozoic and Cenozoic rocks, but descriptions of many of these have never been published because their relationship to European species was not clear. To obtain the needed European material for comparison was the primary purpose of Doctor Bassler's expedition.

The first two weeks were spent in company with Dr. Ferdinand Canu, of Versailles, the most eminent student of microfossils on the Continent, who has been the joint author with Doctor Bassler of several large publications on the American fossil bryozoa. At this time Doctor Canu presented to the Museum his entire collection of French Cenozoic and Mesozoic fossils, containing at least a hundred thousand specimens fully labeled as to horizon and locality.

Doctor Bassler proceeded to the Rhine Valley, where he studied in succession the broad plain around Strassburg, the valley to Mainz, and the valley of the Main River from Mainz to Frankfort. In the Rhine gorge a first-hand knowledge was obtained of the Devonian stratigraphy of this classic area and important collections of Devonian fossils were secured.

Various regions in Germany were studied with profit both in the amount of good study material secured and in the information regarding stratigraphic relationships. The classic Mesozoic region north of the Hartz Mountains was visited in company with Mr. Ehrhard Voigt, an enthusiastic student of microfossils at Dessau, Germany. Mr. Voigt also accompanied Doctor Bassler to other regions celebrated in German stratigraphy, particularly the potash areas around Stassfurt, the drift region around Dessau, and other regions to the north, and finally to the island of Rügen on the Baltic.

At the town of Sassnitz on Rügen were located the " Kreideschlemmerei " or chalk-washing establishments. An important industry has been developed around the use of chalk for various whitening purposes, but the chalk must be pure and free from fossils and flint fragments. To accomplish this, the chalk is passed through the washers and all the fine and coarse débris is sieved out and thrown aside, leaving the water with its dissolved material to settle. In the pile of débris resulting from such washing many fossils have been discovered in this area. Not only were many excellent echinoids, brachiopods, and other large fossils picked up in the dump heap but literally billions of microfossils were obtained simply by shoveling up several boxes of the fine débris.

MINERAL COLLECTING IN MEXICO

In collaboration with the Mineralogical Museum of Harvard University, Dr. F. W. Foshag, of the National Museum, conducted field work in that part of the plateau of northern Mexico within the States of Chihuahua, Coahuila, and Durango, for the purpose of collecting representative minerals from that region. Mexico is very rich in minerals, producing, for instance, over 40 per cent of the world's silver, yet but few mineralogical collections have been made there. Doctor Foshag was in the field nearly five months, and over two tons of material was collected and shipped back to Washington. Cordial cooperation was given by Mexican Government officials and by American mining engineers in charge of the mines visited.

Some of the interesting features of the trip are described in the following extracts from Doctor Foshag's preliminary account:

> Sierra Mojada, one of the districts visited, owes its discovery to a band of smugglers attempting to elude pursuit. The ore bodies extend for a distance of 6 kilometers along the foot of a limestone cliff 2,500 feet high. The district is unusual in that lead, zinc, silver, copper, and sulphur have all been mined here. The great length but shallow depth of these mines makes it more economical to work them by the old Spanish methods than by modern ones. Much of the ore is brought to the surface on the backs of peons, often up ladders made of notched logs, popularly called "chicken ladders." It is said that a strong peon will carry loads in excess of 100 kilos (220 pounds.)
>
> In the northeastern part of the State of Durango, near the village of Mapimi, is the Ojuela mine—one of the greatest lead mines of the world. Within this one mine are over 550 miles of tunnels driven to extract the ore. The camp itself is perched on a steep limestone mountain. Before the town, rises an almost vertical cliff of Cretaceous limestone 2,000 to 3,000 feet high. It is in the hills lying at the base of this cliff that the ore bodies lie.

EXPLORING FOR FERNS IN JAMAICA

Dr. William R. Maxon, associate curator of plants, United States National Museum, spent June and July, 1926, in botanical collecting

in the Blue Mountain region of Jamaica. This expedition, made possible through the cooperation of the American Association for the Advancement of Science, the New York Botanical Garden, and the United Fruit Co., had for its specific object the collecting of material needed in the preparation of an account of the ferns of Jamaica. The importance of this study is thus explained by Doctor Maxon:

The ferns of Jamaica were among the first to be described from the New World, but in many instances the names originally given them came later to be applied loosely to related but distinct kinds from other regions, with much resulting confusion. To afford a proper basis for studying the diverse fern floras of tropical America as a whole, it thus becomes of prime importance to know thoroughly that of Jamaica, an end that can be attained, naturally, only with the aid of adequate material.

Of the 500 species of ferns and fern allies described or known from Jamaica, nearly all are found in recent large collections brought to American herbaria from that island; yet there are a few collected by Sir Hans Sloane in the latter part of the seventeenth century, and by Swartz about a hundred years later, that still are known only from the original specimens preserved in European museums. Present field work is concerned therefore in the rediscovery of these "lost" species and of other very rare ones described more recently, but equally also in the discovery of new kinds, and in assembling data as to the distribution, characteristic habitats, habits of growth, and interrelationship of those other species that are comparatively well known.

In all, some 15,000 specimens were collected, which will be of the greatest assistance in the preparation of the proposed monograph of the ferns of Jamaica.

ARCHEOLOGICAL WORK IN CHINA

An archeological survey of the Fêng River Valley, southern Shansi, China, was carried out in the early part of 1926 by Dr. Chi Li, of the Freer Gallery of Art Expedition to China. Carrying letters of introduction to the governor of Shansi and other influential officials, and accompanied by Mr. P. L. Yüan, of the Geological Survey of China, Dr. Chi Li began his trip at T'ai-yüan.

Ancient temples, embellished with iron and stone images, tombs of emperors whose deeds are lost in the haze of tradition, and mounds of prehistoric potteries were found, all of which promise a rich field to the archeologist. An excerpt from Doctor Li's report gives something of the fascinating interest of the exploration.

On the 19th we set out to visit the supposed tomb of the Emperor Shun, and on the way stopped at certain temples in Yün-ch'êng. In *Shansi-t'ung-chih*, it is recorded that the stone pillars of these temples were formerly the palace pillars of Wei Hui-wang (335–370 A. D.), recovered from the ruined city south of An-i Hsien. Some of them are now used as the entrance pillars in Ch'ên-huang Miao and Hou-t'u Miao, and those of Ch'ên-huang Miao certainly

show peculiar features which are worth recording. Two pillars, hexagonal in section and carved with dragons coiled around them, are found at the entrance. The left one is especially interesting, because in the claws of the dragon are grasped two human heads with perfect Grecian features—curly hair, aquiline and finely chiseled nose, small mouth, and receding cheeks. One head with the tongue sticking out is held at the mouth of the dragon, while the other is held in the talons of one hind leg. It is an unusually fine piece of sculpture in limestone, wonderfully spaced and with the most graceful lines. The right one is inferior in its workmanship; evidently the two were not executed by the same hand. I saw 28 of this kind of pillar in the succeeding two days, but most of them were crude imitations. It is possible, however, that some are of the ancient type and were made earlier than others. The whole subject is well worth more detailed study.

ANTHROPOLOGICAL SURVEY OF ALASKA

A reconnaissance of anthropological and archeological matters in Alaska was undertaken during the spring and summer of 1926 by Dr. Aleš Hrdlička, curator of physical anthropology in the National Museum, under the auspices of the Bureau of American Ethnology. An archeological reconnaissance of Alaska presents many difficulties. Although Alaska is as large as one-third of the United States, it has less than 200 miles of good roads; the interior is practically impassable except for short stretches during the brief summer; and transportation by boat is very hard to obtain and very expensive. The people of Alaska, however, were found to be most helpful and generous, and with their help Doctor Hrdlička was able to overcome many of the difficulties encountered. When the Bering Sea was reached, he was fortunate enough to find the revenue cutter *Bear* willing to help, and on it he was enabled to inspect the sites of archeological interest along the Seward Peninsula, the Kotzebue Sound, and through the ~~Arctic Sea up~~ to Barrow.

The journey led from Vancouver to Juneau, thence to Seward, Anchorage, Eklutney, Nenana, and Tananá. From here the route led inland from the junction of the Tananá to the mouth of the Yukon, concluding with the voyage in Bering Sea.

Doctor Hrdlička collected many artifacts of metal, bone, and ivory, examined skeletal remains in many old burial places, examined the differentiation between Eskimo and Indian in physical and cultural characters, and observed the conditions governing the possibilities of the Mongoloid migrations through Bering Sea, which are supposed to have populated the Americas. He was convinced that such migrations were so easy as to have been indeed inevitable, and that the Eskimo and Indian races trace from a common Mongoloid stem, having its American dispersal from the Alaskan peninsula. The ancient Alaskan artifacts discovered point to a high grade of native art, almost on a par with the high cultures of Mexico, Yucatan, and Peru.

CONFERENCE ON THE FUTURE OF THE INSTITUTION

An outstanding event in the history of the Institution was the conference held at the Smithsonian on February 11, 1927, to advise with reference to the future policy and field of service of the Institution. The President, the Vice President, members of the Cabinet, and a group of the foremost American scientists and industrial leaders met under the chairmanship of Chief Justice William Howard Taft to hear addresses on the past record and present great possibilities of the Institution, to inspect a specially arranged exhibit in the main hall of the Smithsonian Building, showing the nature and scope of the researches and publications at present under way, and to discuss informally the most promising directions for the future work of the Smithsonian.

The chancellor, Chief Justice Taft, in opening the conference, reviewed briefly the history of the Institution from 1826, the date of the making of Smithson's will, emphasizing the basic soundness of the charter provided by Congress after eight years of deliberation. But this charter alone did not make the Smithsonian the leader of American science in its early years and a world-renowned agency for the increase and diffusion of knowledge to the present day. The plan of organization outlined and put into effect by the first secretary, Joseph Henry, did that. His plan has proved to be so wise and fruitful of great results that it has never been found necessary to alter it materially. Mr. Taft also emphasized the fact that the Smithsonian Institution is not and has never been properly considered a Government Bureau, this popular misconception having arisen from the fact that the Institution still administers for the Government seven of the public bureaus, which arose from its early activities. Mr. Taft concluded his address thus:

> Joseph Henry had the vision to understand clearly what Smithson meant his foundation to be, and the energy and character to make it that. The Smithsonian has now come to a time when, without the support of the Nation, it can no longer continue to be what Henry made it. And yet the need for just such an Institution as it has been is no less than the need was 80 years ago. In some respects the unique opportunities are even greater. This Institution is not the product of a moment; 80 years of the toil of great men have gone into its making. There is that about it which can not be replaced.
>
> The regents have felt it their duty to reveal to a leading group of representative American citizens what it is and does, and to advise with them what its future shall be. For that reason they have invited you here. They wish you to see the broad and comprehensive scope of the Institution, competing or interfering with nobody, cooperating with all, reaching the basic problems of mankind and of the time, with a view to furnishing the information through which alone they can be solved. They wish you to see what the future possibilities of the Institution are, and if you think them worthy of realization, to advise us as to how we may go about achieving it.

Following the chancellor's address, Doctor Abbot, as acting secretary, spoke on "The Smithsonian Institution—Its Activities and Capacities." Reviewing the origin and growth of the Government bureaus which by direction of Congress remain under Smithsonian direction, he showed how they arose from private Smithsonian initiative, and continued at private Smithsonian cost until they became large public necessities. The activities of the Institution, past and present, were brought together under 13 heads, as follows:

1. It carries on original scientific investigations with its own staff.

2. The Institution subsidizes other researches by men not directly connected with the Institution.

3. It publishes new knowledge, gained by its own and outside workers, in the form of large memoirs and smaller original papers, which it distributes free to 1,500 libraries and learned bodies in every country of the world.

4. The Smithsonian evolved the International Exchange Service and is now the official channel for the exchange of scientific intelligence between the United States and the world.

5. For over half a century the Institution has been building up in the Library of Congress the foremost scientific library in this country, now totaling nearly 700,000 volumes.

6. It fosters the scientific development of schools, museums, and institutions through its free distribution of scientific literature, by the loan of research men, by the gift of over a million specimens, by the distribution of instruments, and by its advice.

7. The Institution cooperates with every department of our Government.

8. It answers by mail an average of 8,000 questions a year on scientific subjects.

9. It gives occasional lectures and courses of lectures and radio talks.

10. It fosters research by conferring medals of honor on eminent discoverers.

11. It procures foreign diplomatic and learned recognition and assistance to expeditions going abroad.

12. It fosters American scientific progress by providing headquarters for the American Association for the Advancement of Science and the American Association of Museums.

13. It administers seven governmental bureaus in addition to the Freer Gallery.

The acting secretary next presented in some detail the wonderful opportunities ahead of the Institution in many lines of scientific research, using as a concrete example his own field of investigation, namely, astrophysics. He stated that there was a vast deal

not yet known about the rays of the sun, which support all life, make all weather, and directly or indirectly supply all power. Knowledge of four things about the sun is particularly needed at the present time:

1. Which rays are best for human health and growth, and at what intensity? How do these intensities change by day, by year, by altitude, and by latitude? Physicians come to the Smithsonian now for information on the influence of sun rays on child health. We can not give them the answer, nor can anyone else, because the investigations have not been made.

2. What rays and in what intensity promote growth and reproduction in the great food and otherwise commercially valuable plants? Are useful modifications of these plants possible by the regulation of radiation? How do plants use solar energy to make chemical energy, and can we improve upon their processes and accomplish photosynthesis directly?

3. Can solar rays advantageously be used directly for power?

4. Can studies of solar variation foretell good and bad weather conditions?

The Smithsonian is particularly fitted through its long experience and trained personnel to attack fundamental problems, and is only restrained from doing so by lack of funds. Examples might be cited for nearly every branch of science.

The acting secretary concluded his address by calling attention to the fact that private endowment is essential for a continuous program of pure science research, and to the unique strategical position of the Institution for the most effective increase and diffusion of knowledge.

After an address by Frederic A. Delano, Regent of the Institution, emphasizing the great opportunity before the Smithsonian of becoming the motivating head of all governmental, quasi governmental, and private research work in the field of pure science, and an introduction to the special exhibits by Assistant Secretary Alexander Wetmore, the conference viewed the exhibits grouped around the main hall. These dealt with the present work of the Institution in anthropology, geology and paleontology, biology, and astrophysics, and also illustrated its activities in the diffusion of knowledge through its publications, its scientific library, its International Exchange Service, and the International Catalogue of Scientific Literature.

After a luncheon for the conferees, which was attended by the President of the United States, an informal discussion was held on the main purpose of the conference, "to advise with reference to the future policy and field of service of the Smithsonian Institution." The chancellor, Mr. Chief Justice Taft, as chairman, turned the direction of the discussion over to Mr. Dwight W. Morrow, regent of the Institution, who in turn called upon a few of the distinguished guests to comment upon the past or the present or the future of the Institution. The speakers included Dr. John C. Merriam, president of the Carnegie Institution of Washington; Dr. William Henry Welch,

director emeritus of the School of Hygiene and Public Health of Johns Hopkins University; Dr. S. W. Stratton, president of the Massachusetts Institute of Technology; Dr. Simon Flexner, director of the Rockefeller Institute for Medical Research; Dr. W. W. Campbell, president of the University of California; Dr. Henry Fairfield Osborn, president of the American Museum of Natural History; Dr. George E. Vincent, president of the Rockefeller Foundation; Mr. Chauncey J. Hamlin, president of the American Association of Museums; Gen. H. M. Lord, Director of the Bureau of the Budget; and Senator Reed Smoot.

The very definite concensus of opinion was apparent from the discussion that the Smithsonian Institution has a most important place to fill in future as the inspirer and coordinator of research in pure science as it had been in the past, and that both governmental and private support should unite in making available more adequate means to enable it to carry on that worthy mission. Chairman Morrow, in closing the discussion, said in part:

I have been deeply impressed with this meeting. I, like Doctor Flexner, have learned much about the Smithsonian to-day. It is a great honor to be associated in any way with such an institution. It is a great honor to those of us on the Board of Regents to have so many distinguished men respond to our invitation to advise with us with reference to the future policy and field of service of an institution which has had so honorable a past. We are particularly grateful to those of you who have taken part in the discussion.

In the course of the conference there has been some discussion of the funds available to the Smithsonian from the Government for those bureaus which are administered by the Smithsonian and those funds available from the original endowment of the Smithsonian. I am sure that General Lord is correct when he tells us that there has been a greater percentage of increase in the Government appropriations for the bureaus administered by the Smithsonian than for the other Government bureaus. We must all remember, however, the point that Doctor Merriam brought out when he referred very beautifully to the work designed to be done by the original Smithsonian Foundation as the "holy of holies." This "holy of holies" remains pretty much as it was when John Quincy Adams induced Congress to grant the charter which makes the work of James Smithson go on. * * *

Now, when one thinks of the splendid history of the Smithsonian Institution, when we think of what devoted men have been doing and are doing upon inadequate salaries, it seems to me that the only way to resolve this dispute as to whether the Smithsonian Institution should be supported by the Government or supported by private benefactions is to get the Government and the private benefactors into such a state of mind that they will vie with each other, the benefactors insisting that they should do it all and the Government insisting that they should do it all.

And in saying good-bye to you, I should like to leave a text in your mind. * * * You will find the text in one of the earlier chapters of Deuteronomy. It reads like this:

"Thou shalt not muzzle the ox when he treadeth out the corn."

That was a practical injunction to a practical people. The ox, who was doing a real work, should not be muzzled. I offer no apology to the devoted

men who have been rendering this Institution service in comparing them to the ox. The ox has a very ancient and a very honorable lineage. If the historians are correct, the ox, as a bearer of burdens, goes back much further than the horse. The ox is perhaps the most ancient burden bearer for mankind. And the devoted men that have been running this institution, what have they been doing? They, too, have been bearing the burdens of mankind, the burdens of the future generations of men.

"Thou shalt not muzzle the ox when he treadeth out the corn."

AWARD OF LANGLEY MEDAL TO COL. CHARLES A. LINDBERGH

The Langley medal of the Smithsonian Institution has been awarded only four times since its establishment. The first three awards were to Wilbur and Orville Wright, to Glenn H. Curtiss, and to Gustave Eiffel, and on June 11, 1927, the fourth award was made, this time to Col. Charles A. Lindbergh for his magnificent nonstop flight from New York to Paris. It thus continues to be characteristically a medal for pioneers in aeronautics. The award was voted to Colonel Lindbergh by the Board of Regents upon the recommendation of a committee of leading aeronautical authorities, and the official notification was made to him in person by the acting secretary at the National Press Club reception in the Washington Auditorium. He said:

The Smithsonian Institution knows how to appreciate the pioneering work of brave men. You will recall, as a single example, our honored one-armed hero, Major Powell, who dared for science the first passage of the uncharted raging waters of the Grand Canyon of the Colorado, strapped in his boat. We are not less stirred to admiration by your own daring in the first nonstop flight from New York to Paris over the boisterous Atlantic through icy clouds that threatened death.

Nor is the Institution failing to appreciate, sir, the precious results in the encouragement of aviation, in the strengthening of ties of international friendship, and in the progress of science, which have already begun to flow from your achievement.

The Smithsonian has in its gift a medal which commemorates the name of Samuel Pierpont Langley, the third secretary of this Institution. He had the audacity to believe in the practicability of the art of flying when all men were ridiculing it; and he adventured his own high reputation as a man of science to lay the groundwork of exact experiments, and to make pioneering flights of large models, which demonstrated the soundness of his faith. The Langley medal has hitherto been presented to Wilbur and Orville Wright, to Glenn H. Curtiss, and to Gustave Eiffel. Thus it is from all points of view the medal of pioneers. It is highly fitting that it should now be awarded to you, sir, the pioneer of audacious, solitary flight to distant shores.

Therefore, acting on the unanimous recommendation of an eminent committee of award, the regents of the Smithsonian Institution have voted to you the Langley medal, and have recorded their action in this paper signed by the chancellor, Mr. Chief Justice Taft, which I now present to you.

The actual medal, in gold, is being struck in Paris. I hope that when it is received you may do the Institution the honor to appear on some suitable occasion and receive it in person.

ANNOUNCEMENT OF AWARD BY THE BOARD OF REGENTS

JUNE 4, 1927.

The Langley medal of the Smithsonian Institution was established by the Board of Regents in 1908 as a tribute to the memory of the late Secretary Samuel Pierpont Langley and his contributions to the science of aerodromics.

This medal has been awarded—

To Wilbur and Orville Wright on February 10, 1909, "for advancing the science of aerodromics in its application to aviation by their successful investigations and demonstrations of the practicability of mechanical flight by man";

To Glenn H. Curtiss on February 13, 1913, "for advancing the art of aerodromics by his successful development of a hydroaerodrome whereby the safety of the aviator has been greatly enhanced";

To Gustave Eiffel, of Paris, on February 13, 1913, "for advancing the science of aerodromics by his researches relating to the resistance of the air in connection with aviation."

Believing that the achievements of Capt. Charles A. Lindbergh entitled him to consideration as a recipient of this medal, the acting secretary of the Institution appointed a committee, which has made the following report:

THE JOHNS HOPKINS UNIVERSITY,
Baltimore, Md., June 3, 1927.

The BOARD OF REGENTS, SMITHSONIAN INSTITUTION,
Washington, D. C.

GENTLEMEN: The committee designated by the Acting Secretary of the Smithsonian Institution, consisting of Dr. Joseph S. Ames, chairman; Admiral D. W. Taylor, Dr. S. W. Stratton, and Admiral H. I. Cone, to consider the award of the Langley medal at this time has unanimously voted that Capt. Charles A. Lindbergh, for his magnificent nonstop flight from New York to Paris, is justly entitled to receive this medal, and recommends that it be awarded to him by the Board of Regents of the Smithsonian Institution.

Very truly yours,

(Signed) JOSEPH S. AMES, *Chairman.*

The Board of Regents has approved the above recommendation of the committee, and I take pleasure in announcing that the Langley medal of the Smithsonian Institution is hereby awarded to Capt. Charles A. Lindbergh for his flight from New York to Paris, made on May 20 and 21, 1927.

WM. H. TAFT,
Chancellor, Smithsonian Institution.

By the Chancellor:
C. G. ABBOT, *Acting Secretary.*

SMITHSONIAN RADIO TALKS

The series of Smithsonian radio talks over station WRC of the Radio Corporation of America, begun in 1923, continued during the year with undiminished popularity. As in previous years, the program was under the direction of Mr. Austin H. Clark. This is obviously an effective method of diffusing knowledge of scientific matters, one of the primary functions of the Institution. An increasing number of the talks have been published as magazine or newspaper articles, thus insuring their permanent preservation. Because

of the increasing demands on the time of station WRC, it became necessary to include the talks on the National Zoological Park, given last year as a distinct series, in the regular series of Smithsonian talks. During the Smithsonian-Chrysler Expedition to Africa, under the direction of Dr. W. M. Mann, letters from Doctor Mann were read over WRC to keep the public informed of the progress of the expedition. Twenty-nine talks were presented between November 24, 1926, and June 29, 1927, as follows:

November 24, 1926: Bringing Home Living Animals from Africa. Dr. William M. Mann, Director, National Zoological Park.

December 1, 1926: Early American Animals—Elephants and Others. Dr. James W. Gidley, National Museum.

December 8, 1926: Shooting Stars. Dr. Willard J. Fisher, Harvard College Observatory (read by Mr. Austin H. Clark).

December 15, 1926: An Observatory Among the Hottentots. Dr. Charles G. Abbot, assistant secretary, Smithsonian Institution.

December 22, 1926: The Invasion of the Snowy Owl. Dr. Alexander Wetmore, assistant secretary, Smithsonian Institution.

January 5, 1927: Natural History in Louisiana. Mr. Percy Viesca, jr., State biologist of Louisiana.

January 19, 1927: Dialogue between Miss Sarah W. Clark and Dr. William M. Mann on the subject of his experiences in Africa.

January 26, 1927: The Antarctic Continent. Prof. Sir Douglas Mawson, the University, Adelaide, South Australia.

February 2, 1927: Some African Reptiles. Miss Doris M. Cochran, National Museum.

February 9, 1927: White Ants or Termites. Dr. Thomas E. Snyder, Bureau of Entomology.

February 23, 1927: The Romance of the Lighthouse Service. Mr. John S. Conway, Deputy Commissioner of Lighthouses.

March 2, 1927: Oyster Farming. Mr. Herbert F. Prytherch, Bureau of Fisheries.

March 7, 1927: American Wild Horses. Dr. James W. Gidley, National Museum.

March 16, 1927: Fishery Products in the Arts and Industries. Mr. Lewis Radcliff, Deputy Commissioner of Fisheries.

March 21, 1927: Beetles; what they are and what they do. Dr. Edward A. Chapin, Bureau of Entomology.

March 28, 1927: Watchmakers as Inventors. Mr. Carl W. Mitman, National Museum.

April 6, 1927: The Study of the Sun. Mr. F. E. Fowle, Astrophysical Observatory.

April 13, 1927: The Sea. Mr. Austin H. Clark, Smithsonian Institution.

April 20, 1927: Frogs and Toads. Miss Doris M. Cochran, National Museum.

April 27, 1927: The Honey Bee. Mr. James I. Hambleton, Bureau of Entomology.

May 4, 1927: Mice. Mr. Arthur J. Poole, National Museum.

May 11, 1927: Fossil Footprints in the Grand Canyon. Mr. Charles W. Gilmore, National Museum.

May 18, 1927: Who owns Potomac Park? Dr. George P. Merrill, National Museum.

May 25, 1927: Museums. Mr. Chauncey J. Hamlin, president, American Association of Museums.

June 1, 1927: The Black Hills of South Dakota. Dr. James W. Gidley, National Museum.

June 8, 1927: Goldfish and Other Aquarium Creatures. Mr. Glen C. Leach, Bureau of Fisheries.

June 15, 1927: Snakes. Mr. Charles S. East, National Museum.

June 22, 1927: The Gold Coast. Mr. Charles H. Knowles, director of agriculture, Accra, Gold Coast.

June 29, 1927: The coins of Asia. Mr. T. T. Belote, National Museum.

PUBLICATIONS

The 12 series of publications issued by the Institution and its branches constitute a chief means of diffusing knowledge, correspondence, exhibitions, and lectures supplementing. The first secretary of the Smithsonian, Joseph Henry, said:

> It is chiefly by the publications of the Institution that its fame is to be spread through the world, and the monument most befitting the name of Smithson erected to his memory.

These publications cover nearly every branch of science, although anthropology, biology, geology, and astrophysics have predominated. As most of the publications present the results of research in pure science, the great majority are naturally technical in character. Two annual publications, however, are intended for the general reader—the Smithsonian annual report and the Smithsonian exploration pamphlet.

The Smithsonian annual report has from the first been enriched with a general appendix made up of a selection of some 30 articles reviewing in nontechnical language recent advances in all branches of science and interesting phases of modern research work. Many of the articles are reprinted from journals which have little or no circulation in this country, and would therefore otherwise probably never be seen by American readers. The following eight titles selected at random from the 30 articles in the general appendix to the 1926 report, which will appear early in the coming autumn, will indicate the character of these papers:

Influences of sun rays on plants and animals.

Excursions on the planets.

Cold light.

The cause of earthquakes; especially those of the eastern United States.

How beavers build their houses.

Fragrant butterflies.

Omaha bow and arrow makers.

Preventive medicine.

Ten thousand copies are printed of the reports and they are distributed free as long as the Institution's quota lasts. The annual Smithsonian exploration pamphlet is a profusely illustrated account of the field expeditions in which the Institution took part during the year. Many of the pictures are extremely interesting, forming a first-hand record of the natural conditions and human activities in far-off parts of the earth. The exploration pamphlet for 1926, issued in April, 1927, described 35 separate expeditions, many of them to remote regions such as South West Africa, East Africa, China, Sumatra, Siam, and the interior of Alaska.

One hundred and eighteen volumes and pamphlets were published during the past year by the Institution and the Government bureaus under its direction. Of these there were distributed a total of 182,846 copies, which included 24,775 volumes and separates of the Smithsonian annual reports, 18,199 volumes and separates of the Smithsonian miscellaneous collections, 17,178 Smithsonian special publications, 110,580 publications of the National Museum, and 10,711 publications of the Bureau of American Ethnology. The titles of the individual papers are listed in the report of the editor of the Institution.

Allotments for printing.—The congressional allotments for the printing of the Smithsonian report to Congress and the various publications of the Government bureaus under the administration of the Institution were practically used up at the close of the year. The appropriation for the coming year ending June 30, 1928, totals $90,000, allotted as follows:

Annual report to the Congress of the Board of Regents of the Smithsonian Institution	$10,500
National Museum	44,000
Bureau of American Ethnology	26,800
National Gallery of Art	500
International Exchanges	300
International Catalogue of Scientific Literature	100
National Zoological Park	300
Astrophysical Observatory	500
Annual report of the American Historical Association	7,000

Committee on printing and publication.—All manuscripts submitted to the Institution for publication either by members of the staff or by outside authors are referred for consideration and recommendation to the Smithsonian advisory committee on printing and publication. The committee also considers matters of publication policy. During the past year five meetings were held and 83 manuscripts were considered and acted upon. The membership of the committee is as follows: Dr. Leonhard Stejneger, head curator of biology, National Museum, chairman; Dr. George P. Merrill, head

curator of geology, National Museum; Dr. J. Walter Fewkes, chief, Bureau of American Ethnology; Dr. William M. Mann, director, National Zoological Park; Mr. W. P. True, editor of the Institution, secretary; Dr. Marcus Benjamin, editor of the National Museum; and Mr. Stanley Searles, editor of the Bureau of American Ethnology.

LIBRARY

The accessions to the libraries of the Institution and its branches, exclusive of the Bureau of American Ethnology, totaled 9,060. The outstanding gift of the year was the John Donnell Smith botanical collection of 1,600 volumes, which will be deposited in the section of botany of the United States National Museum. This library was really presented to the Institution in 1905, but until last year only a part of it had been transferred to Washington. A catalogue of the collection was published by the Institution in 1908.

Decided progress was made during the year on the union dictionary catalogue, especially in connection with the library of the Astrophysical Observatory. This catalogue is designed eventually to include the titles in all the divisions of the Smithsonian library. Efforts to complete broken sets were continued with excellent results, thousands of volumes and parts of volumes being received from the duplicate collection in the Library of Congress and from learned institutions and societies the world over. The aeronautical library was made a distinct division of the Smithsonian library during the year, and was officially designated the Langley Aeronautical Library, in honor of Samuel Pierpont Langley, third secretary of the Smithsonian. Nearly 2,000 volumes were prepared for binding. Material was lent on a semipermanent basis, as usual, to research institutions, to aid special work. The most conspicuous loan of this nature was made to the Johns Hopkins University. Other loans of particular interest were made to the University of Wisconsin and the California Academy of Sciences.

NATIONAL MUSEUM

The congressional appropriations for the support of the National Museum totaled $609,320, an increase of $10,928 over last year. This increase was of material assistance in the regular work, but larger appropriations are essential to a fair realization of the Museum's possibilities. The amounts granted annually are so nearly used up in necessary routine expenditures that little remains for exploration and field work, a vital activity in the proper and balanced development of the Museum. Many opportunities to acquire valuable and unique specimens, which could be obtained with comparatively little expense, are lost each year through lack of an adequate margin of funds to

cover such cases. This need is the greater since the continual encroachment of civilization on natural features of the earth is rapidly bringing about the extermination of many living forms and the destruction of natural formations. Additional funds are needed also for a larger scientific staff. Many extensive collections are now without curators, and in many divisions there should be younger men in training to take the places of those grown old in the service of the Museum. Increases in compensation for the entire staff should also be provided, as the annual efficiency surveys indicate that the majority of the employees are entitled to increases for which at present no funds are available.

The Museum received during the year a larger number of additions to the collections than in any previous year, the total number of new specimens reaching 402,531. The Museum presented to schools 3,717 specimens during the year, 31,747 duplicates were sent out in exchange, and 25,000 specimens were loaned to specialists for study. The year's important accessions are listed in the report of the assistant secretary in charge of the Museum, which forms Appendix 1 of this report. I will mention here but a few of the most interesting additions.

In anthropology there was received the very important collection resulting from Mr. M. W. Stirling's expedition to the interior of Dutch New Guinea, containing much material previously unknown to science. Gen. Tasker H. Bliss presented several hundred specimens of costumes, weapons, weaving, and other native arts from the Philippines. A large collection of pottery and other material resulting from Mr. N. M. Judd's excavations at Pueblo Bonito, N. Mex., was presented by the National Geographic Society. Much valuable material was added to the anthropological collections through the work of the Bureau of American Ethnology, notably that of Dr. J. Walter Fewkes at Eldon Pueblo in Arizona, Dr. Aleš Hrdlička in Alaska, Mr. H. W. Krieger on the upper Columbia River, and Mr. H. B. Collins, jr., in Louisiana and Mississippi.

The department of biology received a large number of important collections, including Siamese mammals, birds, and other forms from Dr. Hugh M. Smith, a large collection of crustaceans from South America gathered by Dr. Waldo L. Schmitt, two important collections of insects from Mr. John D. Sherman and Dr. William Schaus, and zoological material from A. de C. Sowerby working under the auspices of Col. R. S. Clark. Mr. B. H. Swales and Dr. C. W. Richmond each presented valuable collections of birds containing a number of forms new to the Museum, and Capt. R. A. Bartlett donated over 700 specimens of marine invertebrates from Greenland. The botanical collections were enriched by the great gift of Capt. John Donnell Smith, already mentioned, by 11,000 Jamaican plants,

chiefly ferns, collected by Dr. W. R. Maxon, and 9,500 plants from Colombia, collected by E. P. Killip and Albert C. Smith.

Of primary importance among the year's additions to the department of geology are the Washington A. Roebling and the Frederick A. Canfield mineral collections, already mentioned. Exceptionally fine specimens of minerals and ores from Mexico resulted from Dr. W. F. Foshag's expedition to that country. Thirty-five specimens were added to the meteorite section, nine of them new to the collection. The most important accession to the division of stratigraphic paleontology was the collection of 100,000 Mesozoic and Cenozoic fossils from Europe, presented by Ferdinand Canu, of Versailles, France. A partial skeleton of a mammoth was presented by the Venice Co., of Venice, Fla.

The collections of the arts and industries department were increased by over 14,000 specimens. The division of mineral and mechanical technology received an important exhibit illustrating the manufacture of artificial abrasive wheels, a large collection of Patent Office models transferred from the Department of Commerce, and as an addition to the aircraft exhibits, the Navy seaplane NC-4. The textile collections were increased by gifts of silks from H. R. Mallinson & Co. (Inc.), 200 hides, skins, and leather products from the Tanners' Council of America, and a collection of footwear used by different peoples, assembled by the late Frank G. Carpenter and presented by his daughter, Mrs. William Chapin Huntington. The divisions of medicine, wood technology, and graphic arts each received important new material, and the Loeb collection of chemical types accessioned 175 specimens of rare chemicals. The division of history received three fragments belonging with the original Star Spangled Banner, and a white satin evening dress worn by Mrs. Calvin Coolidge in the White House, for addition to the exhibit of costumes of the wives of the Presidents.

The Museum was unusually active in exploration during the past year, many field expeditions having gone out either by means of cooperative arrangements with other organizations or with funds supplied by friends of the Smithsonian. These expeditions will be found briefly described in the Museum report, Appendix 1. The usual large number of meetings and lectures were held in the auditorium and lecture rooms of the Museum. The exhibit of the Smithsonian Institution at the Sesquicentennial in Philadelphia, including that of the Museum, was shown until the close of the exposition on November 30. The exhibits were very favorably received by the public. At the conference held on February 11, 1927, in the Smithsonian Building, the research work of the Museum was represented by specially prepared exhibits. Visitors to all of the

Smithsonian and Museum buildings totaled 1,153,212 for the year, an increase of 50,000 over the preceding year. Ten volumes and 63 separate papers were published during the year, and 110,580 copies of Museum publications were distributed.

NATIONAL GALLERY OF ART

Although the year has been marked by numerous features and events of interest, the two great lines of prospective development have remained practically dormant—these are the erection of a gallery building and the enhancement of the collections by gift and bequest. The meagerness of the offerings of art works is doubtless due in large measure to the well-known fact that exhibition space in the National Museum is entirely exhausted.

The sixth annual meeting of the National Gallery of Art Commission was held at the Smithsonian Institution on December 7, 1926. After the presentation of the annual report on the gallery's activities by the secretary of the commission, a resolution was adopted favoring the establishment of a national portrait gallery, with the present collection of war portraits as a nucleus, to form a unit of the National Gallery of Art. The commission then recommended to the Board of Regents the election of Clarence C. Zantzinger, of Philadelphia, to fill a vacancy on the commission. The acceptance of art works offered to the gallery during the year was then considered.

Four special exhibitions were held in the gallery during the year, as follows: 36 oil paintings of Venice, by Herbert Waldron Faulkner; 49 oil paintings and 14 drawings in pen and pencil, by John Ross Key; 20 portrait drawings in red chalk of members of the Lafayette Escadrille, by John Elliott; and an architectural model of an oriental temple, designed and executed by Charles Mason Remey.

Purchases of paintings from the Henry Ward Ranger fund were three in number—"Still Life," by Frank W. Benson; "Woodland Nymph," by Douglas Volk; and "Man in White," by Cecilia Beaux. These were assigned to various institutions and may later be reclaimed by the National Gallery under certain conditions.

The gallery accepted a number of loans of art works during the year and several loaned in previous years were recalled by the owners.

FREER GALLERY OF ART

Additions to the collection include several pieces of ancient Persian pottery, a thirteenth century Persian painting, and a black schist image of the Indian god Visnu. During the year 123 objects were

submitted for expert opinion or for translations of their inscriptions, besides several Chinese and Japanese texts sent for translation.

The most important work in the preservation of the collection consisted in reconditioning the ceiling of the Peacock Room. The library was increased by the addition of 37 books, 28 periodicals, and 151 pamphlets.

The total attendance for the year was 110,753. Of this number, 367 came for special study in the library and storage rooms. Over a thousand photographs and as many gallery publications were sold during the year. Special mention should be made of the Biblical manuscripts in the possession of the gallery, photographs of which can be obtained on order.

In the field the most important single undertaking was the preliminary excavation, under the supervision of Dr. Chi Li, of a prehistoric site in Shansi Province, China, from which a large amount of valuable material was recovered. A full report of this work is being prepared.

BUREAU OF AMERICAN ETHNOLOGY

The bureau has continued its ethnological researches among the American Indians and the excavation and preservation of prehistoric Indian structures as authorized by act of Congress. In addition it has furnished information on anthropological and archeological subjects to an ever-increasing circle of correspondents. Dr. J. Walter Fewkes, chief of the bureau, continued his systematic researches at Elden Pueblo in Arizona, referred to in last year's report. This interesting ruin is the largest in the Flagstaff region and is closely allied both in masonry and ceramics with the little-known cliff ruins in northern Arizona and the open-air pueblos near St. George, Utah. In the cemeteries east and north of the ruin many skeletons were found, those buried the deepest being surrounded with pottery antedating the glazed pottery of Arizona, including a large number of bright-red bowls with burnished black interiors resembling the ware of the lower Gila and California. A large collection of this pre-Puebloan material was made and is now in the National Museum.

In June, 1927, the chief made a short reconnoissance in the neighborhood of Greenville, S. C., which convinced him that the archeology of the region is complex and would well repay investigation. He selected a site for future exploration and examined several fine collections containing objects of pottery, stone, and clay that have never been figured or described. He obtained photographs of several unique specimens.

Dr. John R. Swanton was engaged during the past fiscal year in the preparation of a bulletin on "The Social and Religious Usages of the Chickasaw Indians," and a similar paper relating to the Choctaw. He also completed a card catalogue of the Timucua words used in the printed works of Pareja and Morvilla.

Dr. Truman Michelson continued his researches among the Algonquian tribes, beginning with the Arapaho of Wyoming, where his work brought out clearly the divergent character of their language as compared with other Algonquian tongues. In Chicago he took the important measurements of all the Blackfoot (Siksika) crania preserved in the Field Museum of Natural History. These measurements, combined with those of material already in the National Museum, should permit the determination of a number of disputed points. In Washington Doctor Michelson prepared for publication by the bureau a paper entitled "Notes on the Buffalo Dance of the Thunder Gens of the Fox Indians" and three new Fox texts.

Mr. John P. Harrington spent the year in the Chumash region of southern California. The Chumash Indians are rapidly taking up the life and language of the whites, and the gathering of information about them is urgent. Mr. Harrington made a very complete linguistic study of the ethnobotany of the Chumash and excavated several rancheria sites which threw new light on the mode of life of these Indians. He also acted as assistant to Doctor Fewkes in the excavation of Elden Pueblo and in recording phonographically the songs of the Hopi Indians.

Mr. J. N. B. Hewitt completed early in the past year the manuscript "Iroquoian Cosmology, second part, with introduction and notes." He devoted considerable time to work upon the manuscript report on the Indian tribes of the upper Missouri River made by Edwin Thompson Denig to the Hon. Isaac Stevens, Governor of Washington Territory, and in recording lexical and grammatical material in the language of the Nez Percé Indians of the Shahaptian linguistic stock. Mr. Hewitt reports, as custodian of manuscripts, that the cataloguing of the manuscripts has been completed and the cataloguing of the phonographic records of Indian music begun. On May 8, 1927, Mr. Hewitt went to Brantford, Canada, where he resumed his researches, studying intensively the rituals, laws, customs, and chants characteristic of the League of the Iroquois. He recorded the text and music of several chants.

Dr. F. H. H. Roberts, jr., joined the staff of the bureau November 1, 1926. His winter months were devoted to a study of the ceramics of the San Juan area of the Southwest. In the spring Dr. Roberts left Washington for the West, making a study of ceramic forms in the Museum of the University of Colorado at Boulder, Colo., and

an investigation of certain caves near El Paso, Tex. On May 13, 1927, he left El Paso for Chaco Canyon, in northwestern New Mexico, where excavation was begun on some slab houses. Between May 17 and June 30, 12 houses, 20 storage cists, and 1 large kiva were excavated. All of the houses were of the semisubterranean, single-room type, rectangular or oval in shape, usually about 15 feet long and 10 feet wide.

Miss Frances Densmore conducted her researches on Indian music in a wider field than in any year preceding. She spent five weeks in Neah Bay, Wash., where more than 140 songs of the Makah Indians were recorded. From Neah Bay she went to Chilliwack, British Columbia, where Indians from a wide territory are annually employed as pickers in the hop fields. More than 125 songs were recorded. Seven manuscripts on the results of this field work were submitted to the bureau for publication.

Dr. Aleš Hrdlička, curator of physical anthropology in the National Museum, during the spring and summer of 1926 made a comprehensive anthropological and archeological survey in Alaska under the auspices of the bureau. In spite of many difficulties encountered, particularly in the matter of transportation, the trip was very successful. The scientific results of this important survey, bearing on the antiquity of man and the archeology of the Eskimos, are given briefly in the report of the bureau.

Dr. Walter Hough, head curator of the department of anthropology, United States National Museum, was detailed to examine recent excavations at Indian Mound, Tenn., reported by the Hon. Joseph W. Byrns. Excavations on the summit of the large burial mound which gives the town its name disclosed several slab-box burials, a number of skeletons, and a few artifacts. Dr. Hough also visited a number of village sites, burial mounds, and flint quarries in the vicinity and collected numerous specimens.

The bureau published during the year Bulletins 82 and 83 and a list of the publications of the bureau. There were distributed 10,711 copies of bureau publications.

INTERNATIONAL EXCHANGES

The total resources for carrying on the exchange service during the year were $52,507, including the congressional appropriation of $46,260. With this sum there were handled by the service a total of 590,879 packages of governmental, scientific, and literary publications, including those received from correspondents in this country for distribution abroad, and those received from foreign countries for distribution to addresses in the United States. This number represents an increase of 110,103 packages over last year's

total, the largest yearly increase in the history of the service. This increase was due largely to the receipt from the Department of Agriculture of hundreds of small parcels formerly sent abroad directly by mail. The total weight of all packages handled was 553,125 pounds.

In accordance with the Brussels convention of 1886, 103 sets of United States governmental documents are now sent through the exchange service to depositories abroad—60 full sets and 43 partial sets. Lithuania and the State of Minas Geraes, Brazil, were added during the year to receive partial sets. China and Egypt adhered during the year to the exchange conventions and full sets of governmental documents are now sent to those countries, the Chinese depository being the Metropolitan Library in Peking, and the Egyptian depository the Bureau of Publications of the Ministry of Finances.

The exchange service, in addition to the routine exchanges, makes every effort, upon request, to assemble special series of publications needed by its correspondents in this country and abroad. For example, among such requests received the past year was one from the botanical department of the Natural History Museum in Vienna for certain American botanical publications. Through the efforts of the service, a considerable part of the material wanted was received by the Vienna Museum, for which the director of the botanical department expressed great appreciation.

NATIONAL ZOOLOGICAL PARK

The year has been a notable one for the park. The largest assemblage of animals ever brought to the park at one time was collected in Africa and brought to Washington by the Smithsonian-Chrysler Expedition; the number of visitors for the year far exceeded that of any previous year; and work was started on a new bird house, which has been badly needed for many years.

The Smithsonian-Chrysler Expedition, financed by Walter P. Chrysler, succeeded in collecting during four months in Tanganyika Territory over 1,000 live animals, birds, and reptiles, which were safely transported to Washington and added to the park exhibits. Dr. W. M. Mann, director of the park, headed the expedition. Among the more striking animals brought back were two giraffes, white-bearded gnu, impalla, reed buck, long-eared fox, greater kudu, eland, wart hogs, leopards, hyenas, civet cats, blue monkeys, and purple-faced monkeys, in addition to many smaller mammals, quantities of birds, and numerous reptiles. Acknowledgments of valuable assistance received by the expedition are given by Doctor Mann in his report appended hereto.

Additions to the collections from all sources totaled 1,535 animals, including 104 born and hatched in the park. Among the mammals born were fallow deer, Barasingha deer, European deer, sika deer, hog deer, American bison, tahr goat, Indian antelope, guanaco, agouti, paca, Rocky Mountain sheep, European brown bear, and rhesus monkey. Losses by death occurred chiefly among animals either very recently received or that had been in the collection for a long time. At the close of the year, the collection consisted of 2,401 animals, including 539 mammals, 1,545 birds, and 317 reptiles and batrachians. Five hundred and ninety-two different species were represented.

The number of visitors to the park for the year was 2,867,235, a record figure. These included 370 schools and classes, totalling 25,000 individuals.

Improvements during the year included a new flight cage, containing two pools, for gulls, terns, and other water birds; alterations in the lion house, bird house, and monkey house to accommodate the animals resulting from the Smithsonian-Chrysler Expedition; the installation of an electric pump with new and larger pipe connections for supplying warmed water to the hippo, tapir, and alligator pools; and a service road to the site of the new bird house.

Construction was begun on the new bird house in the late spring of 1927, and satisfactory progress was made in grading, laying foundations, and brickwork during the rest of the fiscal year. It is hoped that the bird collection may be installed in the new building early in the spring of 1928. This new bird house will form a notable improvement to the park, and the bird collection, shown under modern hygienic conditions, will become one of the most impressive exhibits in the park.

Although the bird house is a step in the right direction, the director calls attention to the fact that several other new exhibition buildings are urgently needed. The collection of animals is one of the finest in this country; the park itself provides probably the finest natural surroundings for a collection of animals of any zoo in the world; but the buildings are now entirely unsuitable and are continually unfavorably commented upon by visitors. The three buildings most needed are a reptile and batrachian house, a small mammal house, and a pachyderm house. The reptile house, in particular, is badly needed immediately; for although reptiles form the most popular and instructive exhibit at all zoos, there is no provision whatever at the National Zoo for their care and proper exhibition.

Attention is called by the director to the fact that nearly all zoological parks maintain restaurants and refreshment stands, profits from which are used to purchase new animals. A limited number of

such concessions at the National Zoo would not only provide better service to the public but would make available funds for the purchase of new specimens for the exhibition collection.

ASTROPHYSICAL OBSERVATORY

Work at Washington included preparations for an attempt to improve on the results of 1923 in measuring the energy-spectra of certain stars. Work was also begun on a new type of pyrheliometer for the solar observations, designed to still further reduce errors.

The important work of revision of the solar radiation measurements was continued vigorously during the year. The records from the Montezuma station from 1923 to date were completely re-reduced, giving values which may now be considered definitive. The observations from the Table Mountain station are being similarly treated, and when completed will permit of the publication of definitive values from that station also.

The observing station at Table Mountain, Calif., which replaces that formerly occupied at Mount Harqua Hala, Ariz., has been in continuous operation throughout the year. Although the number of days on which solar observations may be made does not greatly exceed that at Harqua Hala, the quality of those days for observing, especially from June to September, is vastly superior. The daily results from the Montezuma, Chile, station have been published on the United States weather maps of the day following. They have also been transmitted daily by telegraph to the Argentine Government and to the publisher of a monthly meteorological bulletin containing them. The station on Mount Brukkaros, South West Africa, built and maintained for the Institution by the National Geographic Society, began daily observations under the direction of Mr. W. H. Hoover, director, in December, 1926. It is too soon to decide how favorable the atmospheric conditions at this new station will be. For a considerable part of the time they have been first class, and what unfavorable weather has been experienced, according to old residents of the region, has been unusual.

Correlations of the variation in solar radiation with other results have appeared during the year. Doctor Pettit's observations of ultra-violet solar radiation are closely in proportion with the changes found in total solar radiation by the Smithsonian observers. Doctor Austin has found a very high correlation between changes in the solar constant and long-range radio reception.

Doctor Abbot has found a remarkable regular periodicity of 25⅔ months in the solar variation itself, which, with the sun-spot cycle, accounts for almost the whole change in monthly mean solar

constant results from 1920 to 1927. If this periodicity continues to show in the coming years, it may be possible to forecast at least two years in advance the principal solar changes, and whatever may be found to depend thereon.

INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE

The United States bureau has continued to collect data for an index to the scientific publications of this country. Although postwar conditions forced the catalogue to suspend publication in 1921, every effort has been made by the 33 countries cooperating in the enterprise to keep the organization alive so that publication may be resumed when financial support appears. The latest published list of the scientific journals of the cooperating nations showed a total of 5,496 titles, and this number has since been greatly increased. The United States bureau is at present engaged in revising the list for this country.

A moderate capital fund is all that is needed to enable this great international undertaking to function fully again. For many years this was the most comprehensive bibliography of science available to students and research workers, and nothing has appeared since to take its place.

NECROLOGY

CHARLES DOOLITTLE WALCOTT

Charles Doolittle Walcott, fourth secretary of the Smithsonian Institution, died in Washington February 9, 1927. He had served as secretary for 20 years, and his death is a heavy blow to the Institution at a critical time in its history, as well as a great personal loss to his friends and associates. A detailed biographical sketch of Doctor Walcott will be published in the general appendix to the Annual Report of the Board of Regents, so that here I shall only very briefly outline his career.

Doctor Walcott was born at New York Mills, N. Y., March 31, 1850, and received his early education in the public schools of Utica and the Utica Academy. He did not attend a university but received his training in science from his own field excursions and from books and association with geologists. His first geological work was done in the capacity of assistant to James Hall, famous paleontologist, by whom he was assigned to field researches in Indiana, New York, Ohio, and Canada successively. In 1879 Professor Hall recommended him to the Director of the Geological Survey, Clarence King, and as a result he was made an assistant geologist in the survey. His first work was the study of geological sections from southern Utah

to the Grand Canyon in Arizona, and this was followed by successful researches in Nevada and New England. His announced life work, however, was in the Cambrian, and this he pursued in the intervals of special assignments, presenting a review of his Cambrian studies to the International Geological Congress in London in 1888. In this same year he was appointed paleontologist in charge of invertebrate paleontology in the Geological Survey, and five years later geologist in charge of geology and paleontology. In 1894 he was made director of the survey, succeeding Maj. J. W. Powell. This position he held until 1907, when he came to the Smithsonian as its fourth secretary, succeeding Samuel Pierpont Langley.

During his directorship of the survey he was extremely active in public affairs. He was instrumental in the organization of the Forest Service, the Reclamation Service, and of the Carnegie Institution of Washington, the last of which he continued to serve actively until his death.

As secretary of the Smithsonian, Doctor Walcott furthered its varied activities vigorously and successfully. During his administration the new building for the United States National Museum was brought to completion and opened to the public, and its collections increased enormously; the Freer Gallery of Art was constructed and the great Freer collection installed; the National Gallery of Art was created a distinct administrative unit under the Institution, and plans were inaugurated to provide a suitable national gallery building; and shortly before his death, perhaps the most important step of his administration was taken—the launching of a definite attempt to increase the endowment funds of the Institution. It is greatly to be regretted that he did not live to see the successful outcome of this project, which is expected to develop in the near future, for Doctor Walcott had felt keenly for many years the inadequacy of the present endowment to meet the unequaled opportunities of to-day to promote the increase and spread of knowledge.

The strenuous duties of secretary of the Smithsonian did not prevent Doctor Walcott from continuing his world-renowned researches in Cambrian geology and paleontology, and during the 20 years of his incumbency he published five large volumes of papers on these subjects.

Doctor Walcott received nearly all of the honors which science has to bestow, both in this country and abroad, including many honorary degrees, fellowships in learned societies, and research medals.

As a man, Doctor Walcott earned the lasting friendship and admiration of all those with whom he was closely associated through his nobility of character, his genial, whole-hearted friendliness, and his unswerving devotion to the ideals and purposes of the institu-

tion which he headed. Doctor Walcott was in every sense a worthy successor to the three great secretaries who came before him—Henry, Baird, and Langley.

WILLIAM HEALEY DALL

William Healey Dall, honorary curator of mollusks in the National Museum since 1880, died on March 27, 1927. He was born in Boston, August 21, 1845, and became interested in the study of shells at a very early age. This study he cultivated at every possible opportunity, with the result that after a long and active career he was known at the time of his death as America's leading conchologist, His researches were not confined to that subject, however, and he published noteworthy contributions to paleontology, zoology, meteorology, and nomenclature. He was, in fact, one of the last survivors of the old school of "all-around" naturalists, which has practically disappeared in this day of ultra-specialization.

In 1865 Doctor Dall was put in charge of the scientific work of the International Telegraph Expedition to Alaska, which resulted in his exhaustive volume on "Alaska and its Resources," which for many years was the standard work on Alaska. In 1871 he joined the United States Coast Survey and continued his studies in Alaska, publishing an account of the meteorology of the region and a work entitled "The Coast Pilot of Alaska." In 1884 he was appointed a paleontologist of the United States Geological Survey, which position he filled until his death, holding at the same time his honorary title in the National Museum. During this period he produced hundreds of monographs and smaller papers, chiefly dealing with his specialty, mollusks. Doctor Dall's work was recognized internationally by election to American and foreign learned societies and by many honorary degrees.

FRANK HALL KNOWLTON

Frank Hall Knowlton, custodian of Mesozoic plants in the National Museum, died at his home in Ballston, Va., November 22, 1926. Doctor Knowlton's first association with the Institution was just after his graduation from college, when he worked in the Smithsonian taxidermy shop. Later he was appointed aid, and then assistant curator, in botany, with charge of the herbarium, the modest beginnings of the present great National Herbarium. At this time he began his work on fossil plants, and in 1889 was appointed an assistant paleontologist in the United States Geological Survey. He remained with the survey until his death, at the same time retaining his honorary position with the National Museum.

The full list of Doctor Knowlton's writings in paleobotany contains over 125 titles, and in addition he published nearly 100 papers in botany and ornithology. His publications have been of the greatest value to geology and paleobotany—to the latter, especially his catalogues of the Mesozoic and Tertiary plants of North America, which are used by students of the later floras in all countries. Among zoologists, Doctor Knowlton's "Birds of the World" is considered his most important scientific contribution.

Respectfully submitted.

C. G. Abbot, *Acting Secretary.*

APPENDIX 1

REPORT ON THE UNITED STATES NATIONAL MUSEUM

SIR: I have the honor to submit the following report on the condition and operations of the United States National Museum for the fiscal year ended June 30, 1927:

The total appropriations for the maintenance of the National Museum for this period amount to $609,320, an increase of $10,928 above the appropriations for the year 1926. The additional sums available include $8,918 under the appropriation for preservation of collections to provide for the following: Two assistants in the library, and one in the office of the assistant secretary in charge of the National Museum; the purchase of additional needed supplies; additional freight charges on specimens forwarded to the Museum; and a small sum for the purchase of specimens. Under the appropriation for furniture and fixtures an increase of $1,930 covered one minor promotion on the salary roll, and additional funds to provide housing for new specimens in the collections. Under the amount allotted for heating and lighting an increase of $580 added to small sums gained by retrenchment in other expenses permitted employment of an assistant telephone operator.

The increases that have been indicated have assisted materially in the work of the Museum, but require considerable addition before our organization can operate on a proper basis. Existing appropriations are taken up so largely with the overhead of routine expenditures that there is little available for exploration and field work, an important section of our labors. Great additions to our collections are made annually by many interested friends of the Institution, but the Museum should have adequate funds to enable it to develop researches in the field along logical and continuing lines. There come to the Museum frequent reports of valuable specimens that may be had if some one competent can go to the spot to obtain them. Many of these finds are of such nature that they can not be successfully handled by inexperienced persons, as unless properly collected they may not be worth the cost of transportation; whereas when secured by experienced hands they are highly valuable. At the present time much material of this kind is lost, though with comparatively small expenditure it might be preserved. It may be emphasized that opportunities for acquiring the rare items essential to a national museum are annually decreasing due to the changes wrought by encroaching civilization on natural features everywhere on the earth's

surface, with consequent extermination of living things and destruction of deposits of all kinds. Opportunities now neglected may never offer again. The National Museum of the United States should be in proper situation to avail itself fully of all opportunities to acquire useful materials.

There is need further for definite addition to the Museum staff. At the present time a number of divisions in which there are excellent collections are without curators. Proper training of assistants to handle such collections is a matter that requires years. In a number of our offices younger men should be now at work that they may be fitted to carry on investigations for the care of the collections when those now in charge have gone. Attention may be called also to the urgent necessity for additional clerical assistance for routine work in various offices in the four departments under which our collections are distributed.

The matter of increased compensation for the entire staff, both scientific and custodial, has become one of first importance. The reclassification act of July 1, 1924, provided for increased pay at definite rates if efficiency in the performance of duty is attained. The annual surveys of efficiency required by law have indicated that except in a few instances members of the staff have shown such attention in the performance of assigned duties as to entitle them to increases. With no funds available, it has been impossible to make increases on this basis without additions to the appropriations.

To look ahead to a matter not properly included in the present report it may be stated that in the appropriation for the year 1928 the Congress allowed additional items for one rate increases for the majority of the personnel. This step has given a measure of relief and has had a most favorable reaction on the part of the employees. As a result of this readjustment of the salary roll, made July 1, 1927, the majority of the staff in the fiscal year 1928 are receiving one rate more than the entrance salary established by law for the respective grades. To continue the intent of the reclassification act, further funds for promotion should be provided until the salaries of the various groups attain the average established for each grade. It is earnestly urged that further additions to the appropriations be made until this object can be attained. To do this will provide only proper reward for the conscientious performance of duty, while a better salary status will inevitably react favorably to the interests of the Museum.

As a national organization the Museum has tremendous scope in its scientific activities, as it is expected and desired that it shall maintain collections and be in position to supply information not

only in many branches concerned with natural science but also in the field of history and the manifold phases of industrial development. In the United States to-day there is an increasing group that is definitely interested in science and scientific matters, as is shown in a demand for authentic scientific news on the part of the press, for photographs of interesting scientific objects for publication, and by the general attitude of the public. As our country grows the number of those financially independent who turn to research and investigation as an avocation or with serious desire to assist in human knowledge steadily increases. These persons find in scientific matters both relaxation and inspiration, recreation and serious endeavor. This group now assists tremendously in the furtherance of scientific development and will be a steadily increasing force in that direction in the future. From their financial situation these persons make large contributions toward Federal income in the form of taxes, so that it would seem logical to make a small part of the money obtained in this way available for support of the immediate interests of the contributors in the form of increased appropriations for the governmental bureaus under direction of the Smithsonian Institution.

COLLECTIONS

Additions to the collections this fiscal year have been more extensive than in any preceding year with the exception of 1919, as the total number of specimens received has amounted to 402,531, the largest additions coming in the departments of biology and geology. Material sent for examination and report amounted to 1,371 lots including thousands of specimens. Gifts to schools and other educational institutions came to 3,717 specimens. As exchanges with other institutions, 31,747 specimens of duplicate materials were sent out for which much of value was received. Approximately 25,000 specimens were loaned for study to various specialists.

Following is a digest of the more important accessions for the year in the various departments and divisions in the Museum.

Anthropology.—A collection of specimens obtained by Mr. M. W. Stirling during a prolonged exploration in the interior of Dutch New Guinea has included series of cultural objects entirely new to the collections. There is contained much previously unknown to science, secured from various groups of Papuans and from the pygmies of the Nassau Range in the interior of New Guinea. The entire collection is a gift to the Institution.

Several valuable collections have come through work of the Bureau of American Ethnology in Alaska, among which may be mentioned examples of many ancient and modern artifacts secured by Dr. A. Hrdlička in the summer of 1926. Gen. Tasker H. Bliss has pre-

sented a collection of several hundred specimens of costumes, weapons, weavings, and other objects of value from the Philippines. A noteworthy set of painted sketches, head dresses, and other articles came as a gift from C. H. Heyl, 2d. Mrs. Richard Wainwright presented a number of interesting baskets and pieces of pottery.

In the division of American archeology there was received a large collection of pottery and various artifacts as a gift from the National Geographic Society, representing the material collected by Mr. N. M. Judd during several seasons of field work at Pueblo Bonito, N. Mex. Accompanying this, the society forwarded also material from other sites in New Mexico. The collections of Dr. J. Walter Fewkes from Eldon Pueblo, near Flagstaff, Ariz., of Mr. H. W. Krieger from the upper Columbia River, and Mr. H. B. Collins, jr., from Louisiana and Mississippi, during work for the Bureau of American Ethnology, have resulted in highly valuable material. The most valuable addition to the exhibits of the division of Old World archeology is a collection of Jewish religious ceremonial objects, Maccabean coins, and a number of art works and antiquities received as a loan from E. Deinard.

In the division of physical anthropology there has come a set of casts of skeletal remains of early man from Krapina, a collection of Indian and Eskimo skeletons and skulls from Alaska, and skeletal material from the lower Mississippi Valley.

Biology.—The number of specimens received in this division during the fiscal year amounted to more than 197,000 individual specimens. Of especial importance has been an exceedingly valuable collection of Siamese mammals, birds, reptiles, amphibians, fishes, insects, mollusks, and marine invertebrates, secured through Dr. Hugh M. Smith, Director of Fisheries for the Siamese Government. The Smithsonian-Chrysler Expedition to Africa, under Dr. W. M. Mann, Director of the National Zoological Park, while planned to secure living animals, brought back also valuable series of skins of mammals and birds and other materials for the National Museum. A South American expedition by Dr. Waldo L. Schmitt, under the auspices of the Walter Rathbone Bacon Traveling Scholarship, has brought large collections of crustaceans as well as specimens in many other groups. Mr. John D. Sherman presented a collection of about 20,000 water beetles, a highly important addition to the insect collections. Another large donation was that of about 10,000 moths presented by Dr. William Schaus, honorary assistant curator of insects. Through the unsettled political situation in China, zoological work in that country has been somewhat hampered, but nevertheless certain collections have been received from Mr. A. de C. Sowerby, through the generosity of Col. R. S. Clark.

Mr. B. H. Swales, honorary assistant curator of birds, presented 176 specimens and 7 skeletons of birds, including 46 species and 4 genera new to the Museum. About 100 of these come from the States of Parahyba and Ceará, Brazil. Dr. Charles W. Richmond, associate curator of birds, presented collections that include nine genera and six species hitherto lacking in the collections.

The United States Bureau of Fisheries transferred 338 specimens from various localities, among them the types of seven newly described species. Dr. E. A. Chapin of the Bureau of Entomology, donated a valuable collection of ectoparasites, with other materials. Capt. R. A. Bartlett presented 776 specimens of marine invertebrates, collected off the northwest coast of Greenland during the summer of 1926.

Among the most important additions in the National Herbarium there may be noted 9,500 specimens of plants from Colombia, collected for the Museum by Mr. E. P. Killip and Mr. Albert C. Smith, and 11,000 Jamaican plants, chiefly ferns, secured for the Museum by Dr. W. R. Maxon in Jamaica. There may be mentioned also the receipt of 50,000 mounted plants constituting the remaining half of the John Donnell Smith herbarium, presented to the Smithsonian Institution in 1905, but until this year retained for study in the custody of Captain Smith in Baltimore. The value of these collections to students in American botany can hardly be overestimated.

Geology.—The year has been one of unprecedented prosperity in the department of geology; as, although the number of accessions has not been large, the total number of specimens is overwhelmingly greater than last year, 208 accessions with a total of 176,781 specimens being recorded.

Of primary importance are the Washington A. Roebling and Frederick A. Canfield mineral collections, with their accompanying endowments. The former, gift of Mr. John A. Roebling, comprises approximately 16,000 specimens, embracing almost the entire number of known mineral species, and contains much of interest and value for exhibition. An endowment of $150,000 was provided by Mr. Roebling to make additions to this collection and to assist in research in mineralogy. The Frederick A. Canfield collection, bequeathed to the Institution, contains upward of 9,000 specimens, and is notable chiefly for its fine examples of Franklin Furnace minerals, although containing in addition much of rare beauty and value for exhibition and study. An endowment of nearly $50,000 was provided for the upkeep of the collection.

Dr. W. F. Foshag's exploratory work in northern Mexico in cooperation with Harvard University yielded exceptionally fine examples of minerals and ores. The series of radium minerals was materially

increased by the transfer of those purchased for exhibition at the Sesquicentennial Exposition.

The chief source of material added to the collections in systematic and applied geology was the United States Geological Survey, nine sets of specimens illustrative of published reports being among the transfers. Crystalline masses of white cerussite were donated by the West Toledo Mining Co., Alta, Utah, and large sphalerite and galena specimens by Mr. F. Sansom, of Joplin, Mo.

In the collection of meteorites 35 specimens have been added, an unusually large number, of which 9 are new to the collection. These have come mainly from the Roebling and Canfield collections.

A collection of approximately 100,000 specimens of Mesozoic and Cenozoic fossils from Europe, presented by Ferdinand Canu, of Versailles, France, constitutes the most important accession in the division of stratigraphic paleontology. This, supplemented by collections made by members of the staff, gifts of type, and other valuable material by scientific institutions, universities, and individual collectors, as well as important exchanges, has made accessions in this division unusually noteworthy.

Of fossil vertebrates, the material exhibited at the Sesquicentennial Exposition consisting of unusual fish, turtle, and reptilian skeletal remains from the Niobrara Chalk of western Kansas is of chief importance. A partial skeleton of a large mammoth, discovered and presented by the Venice Co., of Venice, Fla., is of especial interest.

Arts and industries.—The collections in this department were increased by 14,497 specimens during the year. In the section of mineral and mechanical technology an exhibit showing the method of manufacture of artificial abrasive wheels with various by-products is of great importance. There was obtained also the United States Navy seaplane *NC-4*, from the Navy Department, as an addition to the aircraft exhibits. Included with it are several types of airplane engines. Of the greatest importance in the collections have been the Patent Office models transferred from the Department of Commerce, which have added materially to the series illustrating the development of various inventions and the progress of modern industry. These have included patents for practically all divisions of the department.

The textile collections have had added groups of silks from H. R. Mallinson & Co. (Inc.), bearing modern designs based in part upon motifs suggestive of the sea, and including designs representing seaweeds, starfish, corals, dolphins, gulls, and so on. A set of official standards of the United States for American cotton linters, transferred from the Bureau of Agricultural Economics, Department of Agriculture, illustrates the use of fibers obtained during the condi-

tioning of cottonseed for oil extraction by a process of second ginning. The exhibit illustrates use of this material for many purposes. Over 200 specimens of hides, skins, and leather products received from the Tanners' Council of America forms a valuable collection, illustrating commercial use of leather products. A collection of 95 specimens of footwear, collected by the late Frank G. Carpenter during his extensive travels, has been presented by Mrs. William Chapin Huntington.

In the division of medicine an instructive exhibit relating to vision was received from the American Optometric Association, through Dr. Thomas H. Martin. A second exhibit, gift of the American Dental Association, deals with the subject of oral hygiene.

In the section of wood technology the most valuable accession has been a series of 801 wood samples received as an exchange from Yale University School of Forestry, through Prof. Samuel J. Record, coming mainly from various localities in tropical America. New exhibits in this section have included sets of wood products from the Mason Fiber Co., and of a new fireplace fuel made from compressed wood waste by the United Products Co.

To the division of graphic arts there has come a gift of more than 2,000 prints and etched copper plates from Jean Leon Gerome Ferris, including the work of many famous artists, as well as etchings by the donor and his father, Stephen J. Ferris. The gift is one of value and importance. Mr. William Edwin Rudge contributed many examples of prints and samples of aquatone from his printing establishment. In the section of photography Miss Lillian M. Fletcher presented a set of paper negatives made by her father, Abel Fletcher, about 1845, representing specimens of the earliest paper negatives made in the United States.

In the Loeb collection of chemical types 175 specimens of rare chemicals were received. Many new contacts with research workers in the chemical field promise much new material in coming months.

History.—The Maryland Historical Society presented three fragments belonging with the original Star-Spangled Banner, removed many years ago by the original owner of the flag. It will be recalled that this flag was flown over Fort McHenry on September 13 and 14, 1814, and was immortalized by Key in the "Star-Spangled Banner."

Mrs. Calvin Coolidge presented a white satin brocaded evening dress, worn by her in the White House, for the series of costumes of the wives of the Presidents.

Forty-three United States gold, silver, nickel, and bronze coins dating from 1920 to 1926, and 81 medieval and modern European coins were transferred from the Treasury Department. The philatelic collection was increased by more than 5,000 specimens, the ma-

jority of which came from the Post Office Department. In addition there were received further contributions to the precancel postage-stamp collection, presented by the Precancel Stamp Society through its president.

EXPLORATIONS AND FIELD WORK

Many valuable specimens and much new information have come through explorations carried on under special funds available through friends of the Institution, through a variety of cooperative arrangements, or to some extent from funds available from the Museum appropriations.

In anthropology there may be mentioned the field work of Dr. Aleš Hrdlička, curator of physical anthropology, who made an extensive reconnaissance in Alaska as a basis for further archeological and anthropological investigations in a field that has for many years been fruitful of results under the leadership of men traveling in the interests of the Smithsonian Institution. In the spring of 1927 this work was continued through Mr. H. W. Krieger, curator in the division of anthropology, who visited certain areas along the Yukon, and through Mr. H. B. Collins, jr., assistant curator in the same division, and Mr. T. Dale Stewart, of the division of physical anthropology, who went north to Nunivak Island, and were engaged there in exploration of old village sites at the close of the fiscal year. The results of their work will of necessity be held over until the next report, since the close of June found these men out of close touch with Washington. Mr. N. M. Judd has continued work at Pueblo Bonito, N. Mex., as director of the National Geographic Society's Pueblo Bonito expedition, the present field season being planned primarily to permit preparation of a scientific report on the results of this work. Much valuable material has been presented to the National Museum by the National Geographic Society as the outcome of these investigations.

Among the most important expeditions in which the Institution has cooperated has been that to the interior of Dutch New Guinea, by Mr. Matthew W. Stirling, formerly assistant curator of ethnology on the Museum staff, and his associates. The work was carried on through private means supplied by Mr. Stirling and his companions, and was finally developed as a joint enterprise with the Dutch Colonial Government. The principal object was to make anthropological and ethnological studies of the pygmy tribes which it was expected to find on the higher slopes of the Nassau mountains, with supplemental work among the Papuans of the lake plain. After establishing a base camp near the mouth of the Mamberamo River in May, the party made reconnaissance by means of an airplane taken especially for that purpose, and then with definite knowledge of the courses

of the streams that traversed the unknown interior pushed ahead by means of boats up the Mamberamo to the Rouffaar and along that stream to a point where an overland journey was made into the country of the pygmies. Travel was hindered by heavy floods and was beset with many uncertainties through difficulties attendant upon contact with the Papuans, who were excitable and nervous, and fearful of the intention of the invaders. The pygmies of the mountain slopes proved friendly and of entirely different disposition, so that Mr. Stirling and his companions lived among them at ease without necessity for the constant guard required with the natives of the lake plain. The party completed its observations in December. Shipments of specimens to the Museum consisted of 14 large cases containing thousands of implements from peoples living to-day under cultural conditions similar to those of the Stone Age elsewhere. Thanks to the generosity of Mr. Stirling and his companions, the National Museum now possesses one of the finest collections of the kind from New Guinea in existence. The work of the party has been of the highest importance in extending knowledge of one of the few unknown areas remaining on the earth's surface. The courtesy of the Dutch Colonial Government in cooperating in the scientific work, in providing steamer transportation both for the party and for subsequent shipments of supplies, and in furnishing guards to safeguard travel was greatly appreciated, and was of importance to the success of the expedition.

Dr. Waldo L. Schmitt, curator of marine invertebrates during the second year of incumbency under the Walter Rathbone Bacon scholarship, continued field studies of the crustacean fauna of South America, principally on the west coast from Guayaquil, Ecuador, to Punta Arenas, Chile, including visits to the islands of Juan Fernandez and the Falkland Islands, returning by way of Argentina. The collections brought to the Museum are far in excess of those of last year, due in part to a longer period in the field, and include several genera and one family of crustacea found for the first time on the west coast of South America.

Dr. Hugh M. Smith, Director of Fisheries of Siam, an honorary curator of zoology in the Museum, continued field work in Siam. His explorations have resulted in splendid collections of mammals, birds, reptiles, amphibians, mollusks, crustaceans, and insects, which are now being studied with the keenest interest by specialists in the Museum. He himself will undertake the study of the fishes.

The Smithsonian-Chrysler African Expedition to Tanganyika and Kenya under Dr. W. M. Mann, Director of the National Zoological Park, although undertaken to secure living animals, has resulted in additions to the Museum, since collections of birds, mammals, and miscellaneous invertebrates, secured at odd times when the naturalists

of the expedition were not engaged with living animals, were prepared and have been presented to our collections. The collections of birds preserved for dissection is especially notable.

Dr. Alexander Wetmore, assistant secretary in charge of the National Museum, traveling under the Swales fund, sailed from New York on March 22, 1927, for Port au Prince, Haiti. Until the end of April he carried on field investigations in Haiti and then crossed to the Dominican Republic, finally sailing north from Puerto Plata on June 3. Through the interest of Dr. W. L. Abbott, the Museum is in possession of extensive collections of birds, mammals, reptiles, amphibians, plants, and other specimens from Hispaniola. Doctor Wetmore's work in the field was planned with a view to supplementing Doctor Abbott's material when necessary and to gather information on faunal areas and distribution that will be useful in the preparation of reports on the Abbott collections now under way. His work in Haiti included investigations in the vicinity of Port au Prince and the southern peninsula; exploration on the high La Selle, unknown zoologically until this visit; a trip to the interior plain at Hinche; a visit to the caves near St. Michel, famous for their bone deposits; and finally work at Caracol on the north coast. In the Dominican Republic he worked principally on Samaná Bay and in the high interior in the valley of Constanza. His collections have included many items of interest, as among forms already described are a new species of thrush and a new genus of lizards from La Selle.

Owing to disturbed conditions in China, the activities of Mr. A. de C. Sowerby, under the auspices of Col. R. S. Clark, have been greatly curtailed. In spite of this, however, he has succeeded in sending the Museum large and valuable collections, especially of reptiles and fishes which have added notably to our series.

Mr. Clarence R. Shoemaker, assistant curator of marine invertebrates, visited the Marine Biological Laboratory, Dry Tortugas, Fla., during July and August, 1926, under the auspices of the Carnegie Institution of Washington, for the purpose chiefly of making carcinological studies. More than 3,300 specimens of marine invertebrates were collected for the Museum.

Dr. Paul Bartsch, curator of mollusks, in 1926 spent August 10 to 21 at the Tortugas, and August 21 to 24 along the Florida Keys, examining Cerion colonies in continuation of his experiments in heredity with these organisms.

Dr. J. M. Aldrich, associate curator of insects, before the close of the fiscal year departed on an expedition to the western part of the country for the purpose of making collections of insects, principally Diptera, in regions from which few specimens have been received in

the past. His itinerary was planned to extend to California, returning through Nevada, Yellowstone Park, and the Black Hills.

Capt. R. A. Bartlett, a valued volunteer collector for the Museum, as a result of explorations off the northwest coast of Greenland in the summer of 1925, sent in 776 specimens of marine invertebrates.

Dr. W. R. Maxon, associate curator of plants, left Washington in May, 1926, for Jamaica to collect plants, returning early in the following August. His explorations, which were made possible by a grant from the American Association for the Advancement of Science, and the cooperation of the New York Botanical Garden and the United Fruit Co., were conducted in the extreme eastern end of the Blue Mountain Range, and in new areas on some of the high peaks to the westward. The present collection, which is of large extent, with material gathered during several previous trips, comprises ample series of specimens to show local distribution, altitudinal range, and habital forms of most of the 500 species of ferns known to occur in the island. Mr. E. P. Killip, aid, and Mr. Albert C. Smith, collaborator, left Washington for Colombia in October, 1926, and returned in April, 1927, spending approximately six months in collecting plants in the interior regions of that country. The expedition was organized through the cooperation of the New York Botanical Garden, the Gray Herbarium, the Arnold Arboretum, and Mr. Oakes Ames, with the National Museum. The greater part of the work was done in the general vicinity of Bucaramanga, in the Department of Santander, and along the Colombian-Venezuelan border in the Department Norte de Santander. The present exploration is the second in which Mr. Killip has participated in preparation for a report upon the plants of Colombia.

Prof. H. H. Bartlett, honorary collaborator, left last autumn for a year's botanical collecting trip in the East Indies. A considerable collection has already been received from Formosa and at last reports excellent results were being obtained in Sumatra.

Dr. W. F. Foshag, assistant curator of mineralogy and petrology, was in the field from May 23 to late September, 1926, collecting minerals and ores and studying their occurrence at some of the chief mining centers in Mexico. The localities visited were Los Lamentos, Santa Eulalia, La Ceja, Placer de Guadalupe, Cuchilla Parada, and Naica in the State of Chihuahua; Sierra Mojada in the State of Coahuila; and Velardena and Durango in the State of Durango. This expedition, undertaken in collaboration with Harvard University, was highly successful, due largely to the hearty cooperation of the Mexican Government officials and American mining engineers in charge of the properties. Over 2 tons of material were collected, from which representative sets have been selected for both Harvard and the National Museum.

A field trip by Dr. R. S. Bassler, curator of stratigraphic paleontology, during August and September, through France and Germany, included two weeks spent in a study of the Paris Basin in company with Dr. Ferdinand Canu, of Versailles, France, an eminent student of microfossils. Doctor Canu, to commemorate his long association with the paleontological work of the National Museum, presented to it his entire collection of French Cenozoic and Mesozoic fossils, numbering more than 100,000 specimens. Doctor Bassler visited in succession the Rhine Valley, the Valley of the Main, the Early Tertiary areas around Münich, and the classic Mesozoic region north of the Hartz Mountains.

Dr. C. E. Resser spent August and September in field work in the Rocky Mountains in continuation of the studies of Cambrian stratigraphy by the late secretary, Doctor Walcott. He was assisted by Mr. Erwin R. Pohl, of the paleontological staff, whose special interest in the Devonian led him to secure good study collections from these strata whenever encountered.

Under an allotment from the National Academy of Sciences, Mr. Charles W. Gilmore was again enabled to visit the Grand Canyon of the Colorado. While the main object of this trip was to assist in the development of certain educational features of the canyon for the National Park Service, an opportunity was offered to make further collections of fossil footprints from the Supai and the Hermit formations. A noteworthy slab of large size from the latter has the clearly impressed trackways of no less than three different kinds of animals on its surface and will make an unusually interesting exhibit.

In the early autumn of 1926 the Venice Co., of Venice, Fla., reported the discovery of fossil remains of a mammoth and cordially invited the Smithsonian to send and recover the specimen. Dr. J. W. Gidley was detailed for this work, which occupied 10 days. Though the skeleton was by no means complete, the portions found were of sufficient value to amply repay the time and expense required to collect and preserve them. Later in the fiscal year Doctor Gidley was again detailed to visit Curtis, Okla., and Sarasota, Fla., to investigate reported finds of fossil remains. The visit to the first-mentioned locality yielded remains of various Pleistocene mammals. At Sarasota and Zolfo Springs, Fla., a good collection representing a considerable fauna from the west coast was obtained.

BUILDINGS AND EQUIPMENT

Various minor repairs have been necessary to keep the buildings of the Museum in good condition during the year. In the Natural History Building the exterior surfaces of the metal window sashes on the first and second floors have been repainted. Concrete floors

in corridors have also received a coat of paint, and minor repairs have been made to walls and ceilings in various offices. The range housing the study collection of birds was painted and at the same time all the cases were painted white, which has greatly improved the lighting in this room.

In the Arts and Industries Building worn-out downspouts have been replaced and parts of the tin roofs given a coat of metallic paint. New wire screens have been installed and new awnings placed over the skylight over the café. It was also necessary to repaint portions of the walls in several exhibition halls.

In the Smithsonian Building a number of window sashes and doors have been repaired and painted, and the remodeling of the disbursing office, begun in 1926 as a greater measure of precaution during the handling of funds, was completed. Various minor repairs that need not be enumerated were necessary.

The roof and the exterior of two sides of the metal Aircraft Building were painted and the other two sides were touched up where necessary.

In the heating plant the consumption of coal amounted to 3,329 tons of bituminous coal, an amount slightly less than was used in 1926. All told, the heating plant has been in operation nearly 18 years, during which time a number of major repairs and changes have been necessary. It is now in excellent condition. The boilers were inspected by the Steamboat Inspection Service of the United States, and reported in good condition. The new feed-water connections requested by the inspector the preceding year were changed to meet his approval. The elevators have been regularly inspected by the District of Columbia inspector and are equipped with all necessary safeguards to protect passengers. The total electric current produced amounted to 586,041 kilowatt hours, manufactured at a cost of 1.97 cents per kilowatt hour, including interest on the plant, depreciation, labor, and material. The present production is near the maximum for the plant as at present constructed. The ice plant manufactured 368 tons of ice at a cost of $2.49, about 50 per cent less than the contract price on the general supply schedule, the saving on this item for the year being approximately $1,000.

Labor turnover in connection with the heating, lighting, and power plant has been greater than ever before, due to the present low scale of salaries for firemen and under employees, a factor that greatly handicaps the work.

During the year 13 exhibition cases and bases, 253 pieces of storage, laboratory and office furniture, and 1,572 drawers of various kinds were added. These were manufactured mainly in the shops.

MEETINGS AND RECEPTIONS

The lecture rooms and auditorium of the National Museum during the present year were used for 114 meetings that covered a wide range of activities. Governmental agencies that utilized these resources included the Federal Horticultural Board, the Forest Service, the Bureau of Plant Industry, the Biological Survey, and the Extension Service of the United States Department of Agriculture, for various hearings, meetings, and exhibitions of pictures. Members of the Forest Service held a series of meetings during the year dealing with various phases of their work.

The Smithsonian staff convened on December 16 for an illustrated lecture on anthropology by Prof. H. D. Skinner, of Otago University, New Zealand. Dr. Walter Hough addressed the art section of the Twentieth Century Club on January 10.

Scientific societies that met regularly in the building included the Entomological Society of Washington, the Society for Philosophical Inquiry, the Anthropological Society of Washington, and the American Horticultural Society. Meetings were held also by the Vivarium Society, the Wild Flower Preservation Society, the Audubon Society of the District of Columbia, the Aeronautical Society, the Botanical Society of Washington, the Washington Society of Engineers, and the Washington Philatelic Society. The National Association of the Deaf gave an exhibition of motion pictures of the World War and two reels in deaf and dumb language. A special class of Southwestern College of Winfield, Kans., was convened in these halls, and the Mississippi Society of Washington occupied the auditorium for addresses by the Hon. Dennis Murphy, lieutenant governor of Mississippi, and others, the exhibition of motion pictures and a concert.

M. le Prince Ginori Conti, president of the Italian Society of General and Applied Chemistry, Florence, Italy, spoke before the International Union of Pure and Applied Chemistry on the utilization of geothermal power in Tuscany. The American Institute of Electrical Engineers and the American Society of Mechanical Engineers held a joint meeting for an address delivered by W. C. L. Elgin, general manager of the Philadelphia Electrical Co., on the Conowingo hydroelectric development.

The Spanish-American War veterans on January 28 held a reception in honor of the Ambassador from Cuba, Señor Dr. Orestes Ferrara, and Senator R. W. Means, of Colorado, on the anniversity of the birth of the Cuban patriot, José Marti. There was a patriotic gathering of American War Mothers on February 10, with vocal and instrumental music and addresses.

The Masonic clubs of the District of Columbia met in celebration of Washington's birthday, when they were addressed by the Hon.

A. M. Free, Member of Congress from California, on the Life of George Washington and Masonry.

During the late winter and early spring, series of talks were given to students of Howard University on various matters of contact between biological and medical science.

The Fourth National Oratorical Contest and Second International Oratorical Contest were held in the auditorium on April 9, for orations by pupils of private and parochial schools in the Washington Star area. A further meeting held on May 4 was addressed by three competitors.

Federal Post, No. 824, Veterans of Foreign Wars, met on May 28 for an annual memorial service. The finals in the third annual national spelling bee, under the auspices of the Courier-Journal, Louisville, Ky., and 16 associated newspapers. were held on June 23, when the first prize was won by Dean Lucas, of West Salem, Ohio.

From April 19 to 21 the District of Columbia Dental Society occupied the auditorium, lecture rooms, and part of the lobby for an educational campaign dealing with the care of the teeth. The exhibits installed were prepared in cooperation with the United States Public Health Service, United States Army, United States Navy, Children's Bureau of the United States Department of Labor, the division of physical anthropology of the United States National Museum, the Baltimore College of Dental Surgery of the University of Maryland, the Public School Dental Clinic of the District of Columbia Health Department, District of Columbia Dental Hygienist Association, and the District of Columbia Dental Society.

The Daughters of the American Revolution, conservation and thrift committee, attended an illustrated lecture by Herbert N. Wheeler on "The Lure of the Forest."

SESQUICENTENNIAL EXPOSITION, PHILADELPHIA

As stated in the report for last year, the Smithsonian Institution installed an exhibit at the Sesquicentennial Exposition held in Philadelphia during the summer and fall of 1926. As the exposition buildings were delayed in completion, the Institution did not secure possession of the space assigned to it until late in June, so that, though part of our material was arranged by June 30, it was not possible to make complete installation until July. The section assigned to the Smithsonian was one of the first in the Transportation Building to be arranged and made ready for display. The exposition continued until November 30, during which period one or more members of the staff remained in attendance with the exhibit. The exhibits, which were described in some detail in the report for last year, attracted much attention and were favorably received by the public. The

material shown was returned to Washington in December, all in good condition.

SPECIAL EXHIBITION FOR THE SMITHSONIAN INSTITUTION

At the conference of the establishment and Board of Regents of the Smithsonian Institution on February 11, 1927, called to advise with prominent Americans with reference to the future policy and field of service of the Institution, there was arranged in the main hall of the Smithsonian building a special exhibit to demonstrate present activities and research. The National Museum, as one of the major organizations administered by the Smithsonian, was prominently represented through its departments.

For the occasion in question a series of temporary booths was arranged about the entire hall where tables and cases were utilized for the exhibition of specimens, and the walls were given over to charts, diagrams, and photographs. The entire installation was arranged not as a temporary transfer of cases and materials from the National Museum but as a demonstration of research activities on the part of the staff. Each object or each chart displayed, while shown for its interest, was designed to represent some particular phase of science, and the whole was planned to show a cross section of existing researches as developed in the Institution in general.

The department of anthropology was represented by materials to show recent studies in the anthropology and archeology of the Columbia River Valleys of Alaska, the lower Mississippi Valley, and the ancient Indian pueblos of the Southwest, supplemented by certain matters dealing with Old World archeology, with the evolution of man as a species in the animal kingdom, and with the development of the modern American since the invasion of the New World by the Caucasian race.

Projects illustrated in geology and paleontology included studies in elephants and dinosaurs as representative of ancient vertebrate life, and illustrations of investigations into the thousands of fossil species known among the invertebrates, of the highest importance as indicators of the age of ancient rock strata with their included oils and minerals. With these were examples of minerals taken from recent gifts and bequests in the Roebling and Canfield collections, together with materials to illustrate the formation of soil through the disintegration of granite and other rock.

The work comprised in the department of biology is so vast that attempt was made to cover only a few of its various branches. The section devoted to botany, important as the foundation of agriculture, was illustrated by the results of recent explorations on the plant life of tropical America, and by demonstrations of systematic

studies in various groups of plants. In zoology there were shown specimens of reptiles, paintings of fishes, insects, birds, mollusks, mammals, foraminifera, crinoids or sea lilies, and other animals arranged to demonstrate various researches, some of purely scientific interest, others of known economic application. With each section of the exhibits there were in attendance research workers of the scientific staff to explain them fully. The exhibits proved so popular that they were thrown open to the public for several days during the week that followed.

MISCELLANEOUS

The exhibition halls of the National Museum were open during the year on week days from 9 a. m. to 4.30 p. m., while in addition the natural history building and the arts and industries building were open Sunday afternoons from 1.30 to 4.30 p. m. The exhibition halls were closed only on Christmas Day and New Year's Day. Visitors during the year aggregated 1,153,212 persons, an increase of nearly 50,000 over the previous year. Attendance in the several buildings was recorded as follows: Smithsonian, 128,868; arts and industries, 380,430; natural history, 561,286; aircraft, 82,628. The average daily attendance for week days was 3,263 and for Sundays, with only two buildings open, 2,660.

During the year the Museum published 10 volumes and 63 separate papers, while its distribution of literature amounted to 110,580 copies of its various books and pamphlets.

Additions to the Museum library have included 2,492 volumes and 1,299 pamphlets obtained partly by exchange and partly by donation. A large part of the increase has come from the Library of Congress, which has generously presented from its duplicates volumes and parts of volumes needed to complete reference series in the Museum library. The library staff devoted much attention during the year to filling in gaps in sets of periodicals, many of them dating back to the time of the World War when communication with foreign countries was much interrupted and there was consequent loss of mail. These efforts have resulted in a highly gratifying condition in the filling out of many sets. There are at present 37 sectional libraries maintained as important working units of the main library.

Mr. A. Brazier Howell, corresponding secretary of the American Society of Mammalogists, well known for his systematic and anatomical studies on mammals, was appointed collaborator in the division of mammals on December 11, 1926. Miss Isobel H. Lenman, of Washington, D. C., who has long been a benefactor of the national collections, was made a collaborator in ethnology on March 30, 1927. The appointment of Dr. George Grant MacCurdy as collaborator in anthropology was extended for one year, and Mr. Albert C. Smith

was made collaborator in the division of plants for one year from October 1, 1926. Dr. Joseph A. Cushman, internationally known for his work on foraminifera, was appointed collaborator in the division of stratigraphic paleontology for the period of six months beginning May 10, 1927.

Mr. T. D. Stewart was permanently appointed as aid in the division of physical anthropology on March 1, 1927. Miss Doris M. Cochran was promoted from aid to assistant curator in the division of reptiles and batrachians on the same date. On July 1, 1926, Miss Margaret W. Moodey, in the division of geology, was advanced from recorder to aid. Dr. Paul Bartsch, curator of mollusks in the department of biology, was given added appointment on April 18, 1927, as curator of Cenozoic invertebrates in the department of geology.

Under the National Museum there were 97 separations from the service during the fiscal year in question, which amounts to an annual turnover of 27.3 per cent. Most of this has come among the guard and mechanical force. The resulting condition is serious, since it has made it difficult to keep the minor positions filled in a manner necessary for the proper performance of required duties. It is hoped that the slight advances given in salaries on July 1, 1927, may somewhat alleviate this condition, but further increases should be made possible to enable the Museum to maintain a permanent staff in the positions in question.

The Museum was deprived by death of several important members of its scientific staff, all of whom had long been associated with its work. First among these was Dr. Charles D. Walcott, secretary of the Smithsonian Institution and keeper ex officio of the National Museum, whose death came February 9, 1927. Dr. Frank H. Knowlton, of the Geological Survey, honorary custodian of Mesozoic plants since 1894, died on November 22, 1926. Dr. Paul Haupt, associate in historic archeology since 1905, died on February 17, 1926. Dr. William Healey Dall, honorary curator of the division of mollusks and of Cenozoic invertebrates, who was affiliated with the Smithsonian Institution and the National Museum for a period of 58 years, died on March 27, 1927. Another loss by death was that of Mr. Geo. C. McClain, for over 40 years a member of the mechanical force of the National Museum.

Respectfully submitted.

Alexander Wetmore,
Assistant Secretary.

Dr. Charles G. Abbot,
Acting Secretary, Smithsonian Institution.

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APPENDIX 2

REPORT ON THE NATIONAL GALLERY OF ART

SIR: I have the honor to submit the following report on the affairs of the National Gallery of Art for the year ending June 30, 1927:

Although the year has been marked by numerous features and events of interest, the two great lines of prospective development have remained practically dormant—these are the erection of a gallery building and the enhancement of the collections by gift and bequest. The meagerness of the offerings of art works is doubtless due in large measure to the well-known fact that exhibition space in the National Museum is entirely exhausted.

THE GALLERY COMMISSION

The sixth annual meeting of the National Gallery Commission was held in the regents' room of the Smithsonian Institution, December 7, 1926. The members present were Gari Melchers, chairman; Frank J. Mather, jr., vice chairman; W. H. Holmes, secretary; Herbert Adams, James E. Fraser, J. H. Gest, John E. Lodge, Charles Moore, James Parmelee, E. W. Redfield, and C. D. Walcott.

The minutes of the preceding meeting were read and approved and the secretary presented his report on the activities of the gallery for the calendar year. The report touched briefly on affairs of administration, the offerings of art works by gift and bequest, the purchase of paintings from the Henry Ward Ranger fund, the loans and loan exhibits, etc., for the year.

Discussion arose regarding the war portrait collection, and after the expression of various views, the following resolution was adopted:

Resolved, That the National Gallery Commission looks with favor upon the establishment of a national portrait gallery (of which the present collection of war portraits may be regarded as the nucleus) to constitute a separate unit of the collections of the National Gallery of Art.

Mr. Mather, chairman of the committee on Old World art, spoke informally upon the project initiated at the 1925 meeting of organizing an exhibit of old masters in the gallery, saying that he had examined most of those owned in Washington and found them in his opinion not sufficiently representative to make their assemblage as an exhibit advisable, though he favored such an exhibition of old masters of the highest quality such as might be assembled by enlarging the field to be drawn upon.

After discussion of numerous topics of interest, the annual elections were held as provided by the regents' "plan." The present officers of the commission were reelected, as were also the members of the executive committee. The three members of the commission whose terms expire with the close of the present year—Gari Melchers, Herbert Adams, and Charles Moore—were recommended to the Board of Regents for reelection for the ensuing term of four years.

The following resolution provides for filling the vacancy occurring in the membership of the commission, due to the declination of John Russell Pope:

Resolved, That the National Gallery Commission hereby recommends to the Board of Regents the election of Clarence C. Zantzinger, architect, of Philadelphia, to fill the vacancy in the membership of the commission, caused by the declination of Mr. John Russell Pope.

Resolved further, That in the event of the declination of Mr. Zantzinger, the vacancy be filled by the election of Mr. Charles Borie, architect, of Philadelphia.

At 12 o'clock the commission adjourned and proceeded to the gallery to consider, as the advisory committee of the gallery, the acceptance of the art works offered during the year. The result is as follows: Acceptance for the national portrait collection of the 21 World War portrait sketches by John C. Johansen, name of donor withheld; acceptance of the portrait of Rear Admiral Robley D. Evans by August Franzen, N. A., for the same collection, offered by Horatio S. Rubens; acceptance of a marble bust of Proserpine by Hiram Powers, offered by Mrs. George Cabot Lodge; acceptance of 16 portraits in red chalk by John Elliott, of members of the Lafayette Escadrille and a few others of the American men who fought in the World War, offered by Mrs. John Elliott as a memorial to her husband; and tentative acceptance for the gallery of the collection of 10 paintings offered, to be known as the "George Buchanan Coale Collection, Baltimore, Md., 1819–1887," the final assignment of these works for record (to the Institution or to the gallery) to be left to the discretion of the director of the gallery.

SPECIAL EXHIBITIONS HELD IN THE GALLERY

The Herbert Waldron Faulkner Exhibition.—A collection of oil paintings of Venice from Dawn to Dusk, 36 in number, with 18 panel sketches, by Herbert Waldron Faulkner, was installed on screens in the middle room of the gallery November 29 to December 12, 1926.

The John Ross Key Memorial Exhibition.—A collection of 49 oil paintings and 14 drawings in pen and pencil, by John Ross Key (1837–1920) was exhibited as a memorial to the artist by his widow, Ellenore Dutcher Key, in the central room of the gallery from

January 15 to May 10, 1927. The subjects were largely landscapes and gardens, among which were numerous effective portrayals of colonial mansions, located to-day or in the past in Washington and its vicinity.

The John Elliott Memorial Exhibition.—A memorial collection of 20 portrait drawings in red chalk of members of the Lafayette Escadrille, with a few others of the American men who fought in the World War, most of whom lost their lives in the defense of France before the United States entered the war, by John Elliott (1858–1925), was exhibited by his widow, Maud Howe Elliott, February 19 to March 13, 1927. Sixteen of these portraits have been presented to the Smithsonian Institution by Mrs. Elliott while the others, loans to the exhibition on Mrs. Elliott's request, were returned to their respective owners.

The Charles Mason Remey Exhibition.—An architectural model of an oriental temple, designed and executed by Charles Mason Remey, was exhibited at the north entrance to the gallery for a short period. A series of photographs illustrating the exterior of the model, with gardens, terraces, and fountains, were shown.

THE HENRY WARD RANGER FUND

Since the paintings purchased during the year by the council of the National Academy of Design from the fund provided by the Henry Ward Ranger bequest are, under certain conditions, prospective additions to the gallery collections, the list, including the names of the institutions to which they have been assigned, may be given in this place.

Title	Artist	Date of purchase	Assignment
60. Still Life	Frank W. Benson, N. A.	December, 1926	California Palace of the Legion of Honor, San Francisco, Calif.
61. Woodland Nymph	Douglas Volk, N. A.	April, 1927	Atlanta Art Association, Atlanta, Ga.
62. Man in White	Cecilia Beaux, N. A.	do	The Brooklyn Institute of Arts and Sciences, Brooklyn, N. Y.

ACTIVITIES OF THE AMERICAN FEDERATION OF ARTS, AND THE FEDERATION OF WOMEN'S CLUBS

The American Federation of Arts, and the Federation of Women's Clubs continued their work on behalf of the gallery, furthering its interests with propaganda, lectures with the use of lantern slides and photographic prints, and circulating exhibits of paintings.

ART WORKS ADDED DURING YEAR

Accessions of art works by the Smithsonian Institution, subject to transfer to the National Gallery on approval of the advisory committee of the gallery commission, are as follows:

Twenty-one original studies in oil by John C. Johansen, N. A., utilized by Mr. Johansen in the execution of his great work, "Signing the Peace Treaty, June 28, 1919," and in portraits of distinguished leaders of America and the allied nations in the World War, now installed in the National Portrait Gallery, received through Mrs. James C. Rogerson, the donor's name being for the present reserved, here listed as:

Premier Vittorio Emanuele Orlando, Italy.
Hon. Jules Jusserand, France.
M. Louis-Lucien Klotz, Finance Minister, France.
Hon. Henry White, United States of America.
Premier Georges Clemenceau, France.
General Tasker Bliss, United States of America.
Premier Ignace Jan Paderewski, Poland.
Hon. Frank Lyon Polk, Assistant Secretary of State, United States of America.
Hon. Earl of Balfour, Great Britain.
Marechal Joseph Joffre, France.
M. Stephen Pichon, Foreign Minister, France.
President Woodrow Wilson, United States of America.
Hon. Earl of Balfour, Great Britain, at his home.
Marechal Joseph Joffre, France, at army headquarters, Paris.
Hon. Henry White, United States of America, in room occupied by the American Peace Conference, Paris.
Field Marshal Earl Douglas Haig, England, at army headquarters, London.
Hon. Bonar Law, Great Britain, at No. 10 Downing Street, London.
Interior of the Salle de Glaces, Palais de Versailles, where the treaty was signed.
Premier David Lloyd George, Great Britain.
Premier Ignace Jan Paderewski, Poland, in conference.
Preliminary study for composition of the painting, "Signing the Peace Treaty, June 28, 1919."

Bust of "Proserpine" (marble) by Hiram Powers (1805–1873), with marble pedestal; and three Japanese panels; presented by Mrs. George Cabot Lodge, Washington, D. C.

Three busts by Henry Kirke Brown (1814–1886), N. A. 1851, presented by Mr. H. K. Bush-Brown: Life-size bust in plaster of Gen. Winfield Scott, modeled from life in Washington about 1858, used as a study for the equestrian statue of General Scott in Scott Circle, Washington, D. C.; life-size bust in marble of William Cullen Bryant (about 1850, before the poet had a full beard); life-size bust of Greco-Roman head modeled in Rome about 1844 and cast in bronze in Mr. Brown's studio in Brooklyn, N. Y., about 1850. This

is one of the first castings made in this country and is of special interest on this account.

Sixteen portraits in red chalk by John Elliott (1858–1925) of the original members of the Lafayette Escadrille and a few others of the American men who fought in the World War. Gift of Mrs. Maud Howe Elliott, widow of the artist, as a memorial to her husband, for the national portrait collection.

Richard Norton.
Victor Emmanuel Chapman.
Norman Prince.
Hamilton Coolidge.
Quentin Roosevelt.
Paul Pavelka.
Bert Hall.
James R. McConnell.
Richard Stevens Conover, 2d.
Georges Thénault.
Gervais Raoul Lufbery.
Edmond Charles Clinton Genet.
Alan Seeger.
Elliot Christopher Cowden.
William Thaw.
Philip Rhinelander.

Mrs. Elliott has added to her gift photographic enlargements of four similar portraits belonging to the set of 20 shown in her memorial exhibit, the originals of which were loaned by their respective owners, as follows:

Raynal Cawthorne Bolling (from the United States Steel Corporation).
Richard McCall Elliot, jr. (from Mrs. Richard McCall Elliot, Bryn Mawr, Pa.).
William Halsall Cheney (from Mrs. William H. Schofield, Peterborough, N. H.).
Kiffin Yates Rockwell (from Mrs. Kiffin Rockwell, Asheville, N. C.).

Landscape in oil entitled "The Brook" (a sketch from nature of Bouquet River in the Adirondack Mountains) by Clinton Ogilvie (1836–1900), A. N. A. 1864; and a portrait bust in bronze, on marble plinth, of Clinton Ogilvie, by Paul Wayland Bartlett (1865–1925), N. A. 1917; presented by Mr. William Francklyn Paris, of New York City.

Seven water-color paintings by Henry Bacon (1839–1912), given in memory of the artist by his widow, Louisa Lee Bacon, as follows:

The Parthenon, east façade (the Piraeus and hills of Parnassus in the distance).
The Parthenon (west façade).
The Erechtheum.
General View of the Acropolis at Sunset.
Central Metope of the Frieze of Phidias, Parthenon.
Theater of Dionysus (the violet-crowned Hymettus in the distance).
Temple of Nike Apteros (the Piraeus and Phaleron in the distance).

Centenary medal (bronze) issued in commemoration of the one hundredth anniversary of the company, presented by the president and directors of the Baltimore & Ohio Railroad. Mr. Hans Schuler, director of the Maryland Institute in Baltimore, designed the medal, which was reproduced direct from his models by the Medallic Art Co., New York City.

A portrait bust in marble of Dr. Alexander Graham Bell, by Victor Salvatore; presented to the Institution by the American Telephone & Telegraph Co., through Walter S. Gifford, president of the company, upon the occasion of the fiftieth anniversary of the birth of the telephone.

INSTALLATION OF THE ALFRED DUANE PELL COLLECTION

The Smithsonian Institution was able to avail itself of the services of Dr. S. W. Woodhouse, jr., associate of the Pennsylvania Museum and School of Industrial Art, Philadelphia, to identify, classify, catalogue, and label the porcelain, glassware, silverware, and other art objects of the Alfred Duane Pell collection. A selection of typical examples of the various groups is displayed in the Pell alcove of the National Gallery. The remainder of the collection, comprising duplicates of the porcelains together with other interesting varieties of objects, is, due to lack of space in the gallery, installed on the gallery of the west hall in the arts and industries building of the National Museum.

The porcelains of this collection are mainly old English, Continental European, Russian, and Chinese, though there are a few individual pieces from elsewhere. Probably the most attractive group comprises 25 examples of pate sur pate by Solon from the Minton factory. The Worcester factory is represented by many pieces from the time of Doctor Wall, and his immediate successors including typical old patterns. From the Sevres factory are examples from almost the very beginning of the factory down to the latter part of the nineteenth century, including pieces from the services of Charles X, Louis XVIII, Louis Philippe, and Louis Napoleon, with biscuit busts of many French notables. There are many pieces from old Paris. The Meissen factory is represented by examples of the older wares as well as by more modern figures and animal pieces. Groups from Vienna and from the St. Petersburg Imperial Factory add interest to the collection. The products of the latter were made exclusively for the royal family. Mention should also be made of the large group of Chinese blue and white reticulate ware of the eighteenth century.

LOANS ACCEPTED BY THE GALLERY

Eleven family portraits of the Rosses of Balnagown, Scotland, by British masters, and three artistic family antiquities, loaned by the Bruce Corporation (Ltd.), of Kildary, Scotland, and Wilmington, Del., through Col. Sir Charles Ross, as follows:

Admiral Sir. John Lockhart Ross, by Sir. Joshua Reynolds (1723–1792).
The Hon. Grizel Ross, by William Hogarth (1697–1764).

The late Sir Charles W. A. Ross, by Sir Henry Raeburn (1756–1823)

Miss Grace Lockhart, by Sir Henry Raeburn (1756–1823).

The Earl of Lauderdale, artist undetermined.

Lady Mary Ross (wife of the late Sir Charles W. A. Ross), by Sir Thomas Lawrence (1769–1830).

Gen. Sir Charles Ross, by George Romney (1734–1802).

Sir William Wallace, artist undetermined.

John Graham of Claverhouse ("Bonnie Dundee"), artist undetermined.

Lucy Walters and the Duke of Monmouth, by Sir Peter Lely (1618–1680).

"Lady Standing by Tombstone," by Thomas Gainsborough (?) (1727–1788).

Large silver tray, "Presented by the two Assurance Companies and Merchants of London To John Lockhart, Esq., Captain of His Majesty's Ship *Tartar* For his Gallant Service in protecting the Trade of the Nation by taking many French Privateers, in the years 1756 and 1757."

Gold cup with separate cover inscribed: "Presented by the Society of the Merchant Venturers of the City of Bristol to Captain John Lockhart, Commander of His Majesty's Ship *Tartar* for the Important Services He Rendered to the Trade of that City, by Ably Protecting Her Merchantmen and Distressing Numerous French Privateers, 1758."

Chair which belonged to Sir William Wallace (between 1290 and 1310).

Classical bust in bronze, lent by Miss Helena Lodge, Washington, D. C.

Portrait of Thomas Amory, of Boston, by Gilbert Stuart, lent by Miss Helen Amory Ernst, Washington, D. C.

Sculptured figure of a howling coyote (plaster cast), by Edward Kemeys, lent by Mrs. Edward Kemeys, to be placed with her collection of similar objects in the temporary possession of the gallery.

Five paintings by French masters, lent by the Hon. and Mrs. Louis A. Frothingham, North Easton, Mass., as follows:

The Lake (panel), by C. F. Daubigny.

Twilight on the River Oise (panel), by C. F. Daubigny.

The Little Marauders (panel), by Narcisse Diaz.

Groups of dogs, fox hounds (panel), by Narcisse Diaz.

The Setting Sun (canvas), by J. B. C. Corot.

Plaster death mask of Napoleon Bonaparte (signed by Anton Marchi), described as the orignal death mask of Napoleon, lent by Mrs. L. R. Hoover, Washington, D. C.

Portrait bust in plaster of President James Monroe, by Margaret French Cresson (Mrs. William Penn Cresson), lent by Mrs. Cresson, Washington, D. C.

Portrait of Theophilus Parsons, first chief justice of Massachusetts, by Gilbert Stuart, lent by Mr. Theophilus Parsons, his great-grandson, Washington, D. C.

LOANS BY THE GALLERY

The American Federation of Arts borrowed three paintings for a special exhibition given by the Carnegie Public Library, Fort Worth, Tex.: "June," by John W. Alexander, which has since been

returned to its place in the gallery; and "By the River," by Stephen Bosnay, and "Schloss Monrepos," by Hermann Göhler, which are still being shown on circuit in Texas.

DISTRIBUTIONS

Paintings lent to the gallery have been withdrawn by their owners during the year as follows:

Portrait of Alexander Hamilton, by John Trumbull; portrait of Fisher Ames, by Gilbert Stuart; and River Landscape with Cattle, by Constant Troyon; withdrawn by Mr. John E. Lodge.

Five paintings by Old World masters and four by American painters: Portrait of Admiral Vernon, by Thomas Gainsborough; The Ford, by J. B. C. Corot; Garden at Giverny, by Claude Monet; Saskia as "Minerva," by Rembrandt Van Rijn; Children on the Beach, by T. Sorolla; Sunset, by George Inness; Olive Trees at Corfu, by John Singer Sargent; portrait of Mrs. Samuel Miller, by John Wesley Jarvis; and portrait of Sarah Cresson, by Thomas Sully; withdrawn by Mrs. Breckinridge Long.

Sixteen examples of the works of old masters: Portrait of a boy, by Sir Henry Raeburn; portrait of an Irish gentleman, by John Hoppner; portrait of Viscountess Hatton, by Sir Peter Lely; portrait of a gentleman, by Sir Godfrey Kneller; portrait of Judith von Volbergen, by P. Moreelse; landscape, by Richard Wilson; landscape, by Gainsborough; small landscape, by Gainsborough; landscape, by Constable; The Doctor's Visit, by Jan Steen; Scene in Venice, by Guardi; portrait of Sir Wm. Boothby, by Sir Joshua Reynolds; portrait of Mrs. Price, by Sir Joshua Reynolds; portrait of woman, by Drost or Vermeer; Turkish scene, by Diaz; and Grand Canal, Venice, by Canaletto; withdrawn by Mrs. Marshall Langhorne.

The Annunciation, attributed to Lorenzo Sabbatini; withdrawn by the Misses McKey, of New York City.

Six paintings and a bas-relief: Madonna and Child, by Francesco Bissolo; portrait of Mrs. Richard Eaton, by Charles Willson Peale; Spanish interior, by Juan Galves, 1598; Holy Family, attributed to Francesco Francia; portrait, Man in a Red Coat, attributed to Thomas Hudson, master of Sir Joshua Reynolds; portrait, Man Holding a Lily, artist unknown; and portrait, Sarah Redwood Lee (bronze bas-relief), by Augustus Saint-Gaudens; withdrawn by Miss Sarah Redwood Lee.

Two portraits of the late President Warren Gamaliel Harding, by E. Hodgson Smart, lent by the artist, were sent to the United States Capitol, care Senator Simeon D. Fess, at the request of the artist.

Portrait group of Mrs. Wheeler and her sons, by Thomas Sully; withdrawn by Capt. William D. Wheeler, United States Air Corps.

LIBRARY

The gallery library, by gift, purchase, and subscription, has reached a total of upward of 1,500 volumes, pamphlets, and periodicals.

A portfolio of unframed water color sketches, by William H. Holmes, has been presented by the artist.

COPYING

Mr. Wilbur Dean Hamilton, of the department of fine arts of the Massachusetts Normal Art School, Boston, Mass., completed a copy of the Romney portrait of John Wesley, belonging to the John H. McFadden collection, which copy is to be placed in the Wesley room in Lincoln College, Oxford, England. The privilege of making the copy was granted by the trustees of the collection, which is a loan to the gallery.

PUBLICATIONS

Holmes, W. H. Report on the National Gallery of Art for the year ending June 30, 1926. Appendix 2, report of the secretary of the Smithsonian Institution for the year ending June 30, 1926, pp. 50–60.

——— Plea for a National Gallery of Art. Art and Archaeology, Vol. XXIII, No. 2, February, 1927, pp. 50–69. 21 illustrations.

Catalogue of an exhibition of oil paintings of Venice from Dawn to Dusk, by Herbert Waldron Faulkner, on view in the central room of the National Gallery, Natural History Building, United States National Museum, November 29 to December 12, 1926. Washington, 1926, pp. 1–2.

Catalogue of a collection of paintings and drawings by the late John Ross Key (1837–1920), on view in the central room of the National Gallery, Natural History Building, United States National Museum, January 15 to February 6, 1927. Washington, 1927, pp. 1–3.

Catalogue of a memorial collection of drawings in red chalk by John Elliott (1858–1925) of the original members of the Lafayette Escadrille and a few others of the American men who fought in the Great War, on view in the central room of the National Gallery, Natural History Building, United States National Museum, February 19 to March 13, 1927. Washington, 1927, pp. 1–11.

Respectfully submitted.

W. H. Holmes, *Director*

Dr. Charles G. Abbot,
Acting Secretary, Smithsonian Institution.

APPENDIX 3

REPORT ON THE FREER GALLERY OF ART

SIR: I have the honor to submit the seventh annual report on the Freer Gallery of Art for the year ending June 30, 1927:

THE COLLECTIONS

Additions to the collections by purchase are as follows:

POTTERY

27.1. Persian bowl, tenth-eleventh century. Sphinx and scroll design carved in the biscuit. Green and black glaze.

27.2. Persian plate, tenth-eleventh century. Animal design carved in the biscuit. White, *aubergine*, yellow and green glaze.

27.3. Persian bowl, twelfth-thirteenth century. Rhages. Decoration painted in colors and gold on a white glaze.

27.4. Persian (or Mesopotamian) bowl, tenth-eleventh century. Sphinx and chequer design carved in the biscuit. Green and black glaze.

PAINTING

27.5. Persian, late thirteenth century.

27.6. Two leaves from a *Manafi al Hayawan*, with paintings in water color and gold set in the text.

SCULPTURE

27.7. Indian, eleventh-twelfth century. Trivikrama, one of the 24 images of Viṣṇu. Black schist.

Work within the collection has been carried forward in the section of Japanese painting and is almost completed at the date of this report. This work includes the reclassification of paintings, the translation of the inscriptions and seals upon them, and the recording of critical opinion. The section of Chinese pottery has also undergone an intensive study and a certain amount of revision in order to keep pace with the knowledge that is slowly being accumulated in this field.

During the year 123 objects have been submitted for an expert opinion upon them or for translations of their inscriptions, and several other Chinese and Japanese texts as well.

Changes in exhibition during the year have involved 4 Japanese screens, 6 Japanese panels, 2 Whistler pastels, 1 American pottery vase, 23 Chinese panels and 1 scroll, and 8 Indian paintings.

The work of reconditioning the ceiling of the Peacock Room, which was mentioned in the last annual report, was successfully completed during the fall and early winter. The cabinet work involved in it was done in our own shop, and the restoration of the painted surface under the direction of the restorer employed by the gallery. The latter also put into safer condition the leather panel with the peacock design at the south end of the room and one painting by D. W. Tryon. In the oriental section two Chinese panels and two Japanese screens have been remounted and restored.

Additions to the library by purchase and gift include 37 volumes, of which 2 are in Japanese; 28 periodicals, and 151 pamphlets. A list of these accompanies this report as Appendix A (not printed). Thirteen volumes have been rebound.

The demand for photographs is constant, and in meeting it the gallery is building up its store of negatives. There are now 1,158 fine-art subjects available for purchase, at cost price, in sizes 5 by 7, 8 by 10, 11 by 14 and 18 by 22; and 24 subjects in post-card form. In addition to these, the gallery possesses 829 negatives of the Biblical manuscripts, from which photographs can be obtained on order. One thousand two hundred and forty-six photographs, 34 lantern slides, and 1,569 post cards have been sold during the year, and one rubbing from a Chinese carved stone, which was made to order. Of the gallery publications, 332 gallery books, 583 descriptive pamphlets, 256 *Synopsis of History*, and 9 floor plans have been sold.

THE BUILDING

For several months the shop was occupied with the tedious and delicate repair work necessitated by the reconditioning of the ceiling of the Peacock Room. Other shop work includes the work on exhibition cases and pedestals, the making of various articles of equipment, and ordinary repair work.

The most marked change in the appearance of the building has been occasioned by the substitution of grass plots for the four corner sections of brick work in the court. It is thought that this change will not only yield a greater pleasure to the eye but that it will materially decrease the amount of radiated heat during the summer months. A detailed report made by the superintendent is submitted herewith as Appendix C (not printed).

ATTENDANCE

The gallery has been open every day with the exception of Mondays, Christmas Day, and New Year's Day from 9 until 4.30 o'clock, and until 12 o'clock on June 11, the day set aside to honor Colonel Lindbergh on his return from France. The total attendance for

the year was 110,753. The aggregate Sunday attendance was 31,254, making an average of 601; the week-day attendance amounted to 79,499, with a daily average of 307. Of these visitors, 823 came to the main offices—367 to take advantage of the facilities for study in the library and storage rooms; 84 to see the facsimiles of the biblical manuscripts; 7 to make drawings and sketches; 53 to submit objects for examination, 142 for general information, and 197 to examine or purchase photographs. Forty-five persons interested in museum work made a study of the building and its equipment. Twenty-four groups of people, representing several schools and other organizations, were given docent service in the galleries.

FIELD WORK

The most important single undertaking of the past year in the field was the preliminary excavation of an interesting prehistoric site in Shansi Province, from which a large amount—76 cases in all—of valuable material was recovered. This piece of work was carried out last autumn under the immediate supervision of Dr. Chi Li, whose full report is now in course of preparation. A general account of the activities of the field staff is, however, contained in Appendix B, submitted herewith (not printed).

PERSONNEL

Mr. Herbert E. Thompson, Boston, with his assistants, C. E. Durham and Alfred Lowe, worked on the preservation of the Peacock Room and one oil painting.

Mr. Y. Kinoshita, of the Museum of Fine Arts, Boston, worked at the gallery during the winter months on the preservation of oriental paintings.

Mr. A. G. Wenley, field assistant, spent the winter in study at the Collège de France, Paris.

Mr. C. W. Bishop, associate curator, has been temporarily recalled to the gallery.

Respectfully submitted.

J. E. Lodge,
Curator, Freer Gallery of Art.

Dr. C. G. Abbot,
Acting Secretary, Smithsonian Institution.

APPENDIX 4

REPORT ON THE BUREAU OF AMERICAN ETHNOLOGY

SIR: I have the honor to submit the following report on the field researches, office work, and other operations of the Bureau of American Ethnology during the fiscal year ended June 30, 1927, conducted in accordance with the act of Congress approved April 22, 1926. The act referred to contains the following item:

> American Ethnology: For continuing ethnological researches among the American Indians and the natives of Hawaii, the excavation and preservation of archæologic remains under the direction of the Smithsonian Institution, including necessary employees, the preparation of manuscripts, drawings, illustrations, the purchase of necessary books and periodicals, and traveling expenses, $57,160, of which amount not to exceed $46,000 may be expended for personal services in the District of Columbia.

The chief, as in former years, has endeavored to use this appropriation as economically as possible, being always conscious that the amount available is too small to cover the expense of very extensive field work. His major aim is to make the money go as far as possible in the advancement of our knowledge of the Indian, and the diffusion of the information acquired.

Popular interest in anthropology, especially archeology, has increased greatly during the last decade, and each year replies to queries occupy more of the time of our staff. In spite of the limited appropriation, the bureau has had more investigators in the field during the past year than in any similar period of the present régime.

The systematic researches of the chief at Elden Pueblo, begun in the last fiscal year and treated in the report for 1925–26, were continued through July and August. All of the exterior walls and most of the interior rooms were completely excavated, the rough stone walls of the building showing that it was rectangular in outline and included dwellings, storage rooms, and a single kiva. It extended over a space measuring 145 by 125 feet, oriented approximately north and south. The standing walls range from 2 to 7 feet in height. Elden Pueblo is the largest ruin yet excavated in the Flagstaff region, but there are many others of the same general character still hidden from the light and demanding attention. Although the masonry is crude, the pottery of Elden Pueblo is well made, well decorated, and often highly polished, in a few cases closely recalling glazed ware which was rarely manufactured in prehistoric Arizona. Both the masonry and the ceramics of Elden

Pueblo are closely allied to those of the little-known cliff ruins, Kietsiel and Betatakin, and the open-air pueblos situated near St. George, Utah. The pueblo shows affinities with a culture antecedent to that of Sikyatki and Homolobi, the former being late prehistoric and the latter post-Columbian.

In the midst of graves forming a cemetery on the east side of Elden Pueblo were found subterranean walled depressions, which remind one of those post-Basket Maker rooms or megalithic pit houses which form such a widespread architectural feature, of archaic age, in the Southwest.

Abundant human burials were discovered in cemeteries situated outside the eastern and northern sides. The skeletons were not flexed but lay at full length, their heads generally turned toward the east; those buried at the greatest depth were surrounded by burial offerings, in one instance covered with adobe or hardened clay. About 500 complete pottery vessels were brought back, half of which were unbroken. The collection also contains numerous sherds and other objects, the whole forming the largest collection of pre-Puebloan material of this epoch in the National Museum. In each burial was found an average of five to six ceramic objects such as bowls. This important collection is timely and, for the study of pueblo chronology, is much better than pottery fragments. The collection contains some of the oldest types of that southwestern pottery which was manufactured before the introduction of glazed ware. The specimens are also older than the yellow-red-brown type found at Sikyatki and Homolobi. It contains a large number of bright red bowls with burnished black interiors resembling the Pima and Papago ware of the Lower Gila and California.

In June, 1927, the chief undertook a short reconnaissance to Greenville, S. C., to test the desirability of undertaking field work in the Piedmont region, the archeology of which is little known. Though the trip was a short one, he was much gratified with the prospects for intensive work in the locality and hopes in the autumn to begin elaborate field investigations there. He examined several fine collections containing pottery, stone, and clay pipes, and other objects, none of which has ever been figured or described. He made a number of excursions into the surrounding country and visited several mounds in the Piedmont region, one of which was selected for subsequent explorations. Fragments of pottery picked up on the surface seem to indicate a Cherokee origin. A fine bowl found near the bank of the Savannah River was of Middle Mississippi type and resembled effigy vases from Arkansas. It would seem that the archeology of this region is complex and would well repay investigation, especially as so little attention has thus far been given to it.

The chief obtained many excellent photographs of archeological objects in the collection of Messrs. Thackston and Schwing, of Greenville, to whom, as well as to other citizens of the section, he wishes to express here his thanks for the many kindnesses which he received. The photographs, made by Dowling of Greenville, include several unique specimens.

Dr. John R. Swanton, ethnologist, was engaged during the past fiscal year in reading the proof of his papers on "Social Organization and Social Usages of the Indians of the Creek Confederacy"; "Aboriginal Culture of the Southeast"; and the proof of Mr. W. E. Myer's paper on "Trails of the Southeast." These papers are to appear in the forty-second annual report. Doctor Swanton prepared a paper of over 200 pages on the "Social and Religious Usages of the Chickasaw Indians," which has been accepted for publication. With the help of Miss Mae Tucker, he completed a card catalogue of the Timucua words contained in the printed works of Pareja and Movilla, which he is now engaged in studying and correcting. He also has in preparation a bulletin on the social and religious usages of the Choctaw Indians similar to that on the Chickasaw.

During the fiscal year Dr. Truman Michelson, ethnologist, continued his researches among the Algonquian tribes. In the early part of the year he began work among the Arapaho of Wyoming. Although many years ago he pointed out the divergent character of their language as compared with other Algonquian tongues, the past season's work brought this out even more clearly. It can not be denied that Algonquian elements occur in both the vocabulary and grammar of the language, even though the phonetic shifts are highly complex. But certain lexical elements, as well as certain morphological traits, must apparently be derived from other sources. From these preliminary studies it may be said that Arapaho might almost be called a stock in the making. These circumstances render an exhaustive study of the language highly desirable. In Washington Doctor Michelson prepared for publication by the bureau a manuscript entitled "Notes on the Buffalo Head Dance of the Thunder gens of the Fox Indians." He also corrected the proofs of Bulletin 85, "Contributions to Fox Ethnology."

He furthermore typed the Fox text and English translation of an account of the *wapanowiweni*, a text and translation of the same relating to the mythical origin of a major ceremony of the Thunder gens, and the Indian text of the Thunder dance of the Bear gens. All of these, combined with some additional material, will be presented for publication by the bureau. Doctor Michelson has prepared a brief paper on the St. Lawrence Island Eskimo crania in the United States National Museum, which is to be printed in the

American Journal of Physical Anthropology. This proves statistically that the crania are very uniform, and that, although the cranial index is higher than that of the eastern Eskimo, this could not be considered as showing admixture with a broad-headed type. He spent some time studying the alleged proof of the Australian and Melanesian affinities of certain American stocks, and found that it lacks a sound foundation. On his way west Doctor Michelson stopped in Chicago where he took the important measurements of all the Blackfoot (Siksika) crania in the Field Museum of Natural History. The average height of the male skulls is in round numbers 130 millimeters. These measurements, when combined with those of material in the United States National Museum, should be sufficient to settle a number of disputed points.

Mr. J. P. Harrington, ethnologist, during July and August, assisted the chief in the work at Elden Pueblo, described previously in this report. The rest of the year was devoted to the preparation for publication of field data obtained the previous year in the Chumash region of southern California. The Chumash are fast being acculturated to the languages and mode of life of the Mexican and American people with whom they are in daily contact and it is important that what information is still available be made a matter of record without further delay.

Through the cooperation of Mr. Earl V. Shannon, of the division of mineralogy of the National Museum, the paints used by the Indians were identified chemically, with interesting results, specimens purchased from living Indians and also those taken from graves being used for the purpose.

A very complete linguistic study of the ethnobotany of these Indians was carried out, with special attention to the ancient designations of the parts of the plants and their growth development. The designations of pollen, pistil, stamen, and petal vary widely as we pass from dialect to dialect, various words used for other conceptions being extended to cover them. This same irregularity has also been apparent in comparing the nomenclature of plant species.

Mr. Harrington also read proofs of his Kiowa and Picuris papers, which are now in press. The paper on the Kiowa is important for the classification of the Pueblo Indian languages. In connection with the Picuris paper, Miss H. H. Roberts prepared transcriptions and analyses of Picuris songs which will constitute the most complete study in existence of the music of this tribe.

Early in 1926, Mr. J. N. B. Hewitt, ethnologist, completed the manuscript "Iroquoian Cosmology, Second Part, with Introduction and Notes."

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He has devoted considerable time to work upon the manuscript report on the Indian tribes of the Upper Missouri made by Edwin Thompson Denig to the Hon. Isaac Stevens, Governor of Washington Territory, which has been under consideration for publication by the bureau for more than 10 years. This report has intrinsic merit, as it contains much ethnologic information which it is now impossible to obtain because of changed conditions in the life of the tribes mentioned in it.

Several evenings each week during the autumn and winter Mr. Hewitt devoted to the recording of lexical and grammatical material in the language of the Nez Percé Indians of the Shahaptian linguistic stock of the Powellian classification of Amerindian languages north of Mexico. In this work Mr. Hewitt was assisted by Mr. Mark Phinney, an intelligent and well-educated young man of that tribe, who is employed in the Office of Indian Affairs of the Interior Department.

This work was undertaken primarily to obtain ampler and more accurate linguistic material in this language further to elucidate and confirm certain fundamental conclusions reached by Mr. Hewitt in 1894 in regard to the genetic linguistic relationship of three contiguous northwestern linguistic stocks—namely, the Shahaptian, the Waiilatpuan, and the Lutuamian—of the Powellian classification of Amerindian languages north of Mexico. These fundamental conclusions were embodied in two formal reports to the director of the bureau, having been prepared for his especial use and at his behest as appears in the administrative report of the director for 1894. He approved the findings of both reports, although the last was not delivered until after the administrative report had been written; he had been verbally informed of what the conclusions would be. The first of these reports showed genetic linguistic relationship between the Shahaptian and the Waiilatpuan linguistic stocks of the Powellian classification of Amerindian tongues north of Mexico; and the second showed, likewise, genetic linguistic relationship between the Lutuamian stock of languages and the new group, Shahaptian-Waiilatpuan, established by the findings of the first report. Thus these two formal reports brought together into one linguistic stock the Shahaptian, the Waiilatpuan, and the Lutuamian linguistic stocks of the Powellian classification. To this new grouping of languages was tentatively assigned the name *S h a p w a i l u t a n*, an artificial term made up of the initial syllables of the names of the three combined stocks. Mr. Hewitt has since then found no reason to change his conclusions in these two reports, and his work with Mr. Phinney has only strengthened his findings.

As custodian of manuscripts, Mr. Hewitt reports that, with the exception of a number of cross-references, the cataloguing of the

manuscripts had been completed at the close of the fiscal year, and that the cataloguing of the phonograph records of Indian music was the new work for the year.

On May 8, 1927, Mr. Hewitt went to Brantford, Canada, where he resumed his researches, studying intensively the rituals, laws, customs, and chants characteristic of the League of the Iroquois.

In 1896 Chief Seth Newhouse, a Mohawk, showed Mr. Hewitt a document upon which he had been working for more than 15 years. It purported to be the constitution and by-laws of the League of the Iroquois, in the compilation of which Mr. Newhouse had visited all the Iroquois reservations known to him in both Canada and the United States. Mr. Newhouse was an exceptionally fluent speaker in Mohawk, but instead of recording the material in the Mohawk tongue he painfully recorded it in picturesque broken English. Mr. Hewitt realized that the significance of the materials contained in this document had been lost in the attempted translation and finally convinced Mr. Newhouse that it was his duty to render the ideas underlying the English of the document into Mohawk. This he did in 1898, and the study of this material is one of Mr. Hewitt's present occupations.

Mr. Hewitt also recorded a Cayuga version of the Chant Along the Trails or The Chant of the Roll of the Founders of the Lodge; a Cayuga version of the chant, Over the Great Forest; the music scores of the several chants of the condoling and installation rituals of the league; and an "Introduction" in Cayuga and Onondaga to the second part of the requickening address which is uttered in the principal place of assembly.

Dr. F. H. H. Roberts, jr., archeologist, joined the staff of the Bureau of American Ethnology on November 1, 1926. His winter months were devoted to a study of the ceramics of the San Juan area of the Southwest. Doctor Roberts left Washington April 27 for Boulder, Colo., where a study of early ceramic forms was made in the museum of the University of Colorado.

On May 6 he visited El Paso, Tex., for the purpose of investigating certain caves in a small range of mountains which lie 25 miles northeast of the city, between El Paso and the far-famed Hueco Tanks. There are 28 of these natural recesses in the faces of the cliffs, in most cases just above the tops of the talus slopes. In general they open to the west or northwest. Most of them bear traces of Indian visitors. In the majority of the caves these traces are largely in the form of pictographs painted on the walls with red pigment. The pictures are in great part highly conventionalized and geometric in form. In two instances they were decidedly suggestive of the decorations on pottery from Casas Grandes in northern Mexico.

Three of the caves showed evidences of an occupation extending over a considerable period, judging from the amount of débris and ash on the floors. In the course of two hours' digging, 12 sandals, a number of spear shafts, a fragment of netting, several pieces of cord, portions of rabbit sticks, a few beads, and two potsherds were found.

The sandals are of a rare and interesting form which is not common in the better-known portions of the Southwest. A loop of yucca was twisted to form the edges of the sole and yucca leaves woven back and forth across this framework. Similar specimens have been found in caves in portions of west Texas, east of the present site, and at one or two places in the Mimbres Valley. Two strands of twisted yucca leaves were fastened together at the toe, running back about halfway on either side. The sandal was presumably held in place by passing the toe portion of the "tie" between two toes. The spear shafts were rather elaborately decorated with streamers of yucca fiber. In some instances a small stone point was used; in others a hardened wood point.

On May 13 Doctor Roberts left El Paso for the Chaco Canyon in northwestern New Mexico, where excavation was begun on some slab houses on the top of the south rim of the canyon 9 miles east of Pueblo Bonito and Chetro Kettle. Between May 17 and June 30, 12 houses, 20 storage cists, and 1 large kiva were excavated.

All of the houses proved to be of the semisubterranean single-room variety, rectangular or slightly oval in shape, averaging about 15 feet in length by about 10 feet in width. They were excavated 2½ to 3 feet deep and found to be lined with large slabs of stone, the whole covered with a pole, brush, and plaster superstructure supported on four poles in the interior of the house. In practically all cases there was a small opening to the south, possibly a door. Many of the features of these houses are similar to those which are found in, and considered characteristic of, the highly developed kivas or ceremonial rooms of the communal dwellings of later periods. The storage cists were small oval or circular pits about 2½ feet deep, lined with stone slabs. Houses and storage cists were grouped about the kiva, which is the first of its type to be excavated in the Southwest. The front of the banquette and the wall of the kiva were made of large slabs of stone; the latter were covered with a thick coating of adobe plaster.

Potsherds and other objects of the material culture of the builders of this slab-house village are scarce. The fragments of pottery found, however, are of the type which in southwestern archeology has been given the term "post-Basket Maker." Doctor Roberts believes them to be from a late phase of the post-Basket Maker culture,

probably the end of the period and just prior to the beginning of the pre-Puebloan stage.

Fourteen burials were found and only three had accompanying mortuary offerings. The latter was, in each case, a bowl. Unfortunately the skeletons were in such a poor state of preservation that in all but three instances their removal was out of the question. None of the skulls was deformed, a typical Pueblo trait, and all were dolichocephals or "longheads." A detailed map was made.

SPECIAL RESEARCHES

The research in Indian music was conducted in a wider field during the past year than in any year preceding. In July, 1926, Miss Frances Densmore, collaborator in Indian music, returned to Neah Bay, Wash., to continue her study of the music of the Makah and of Indians from Vancouver Island who have married members of the Makah Tribe. More than 140 songs were recorded, including a group of old songs obtained from a woman of the Quileute Tribe, a particularly isolated tribe living south of Makah.

An exceptional opportunity for the study of Indian music was afforded by the celebration of "Makah Day" on August 26 and by the rehearsals preceding this annual festivity. The program depicted the arrival of a visiting tribe and the entertainment which in the old days would have taken place on such an occasion. The Indians who took the part of visitors arrived in a gaily decorated boat and were formally welcomed and escorted to the place of entertainment, where dances were given by expert Makah dancers. Several of these dances were dramatic presentations of tribal traditions. For example, it was the old belief of the Makah that many sorts of animals, birds, trees, and rocks were once human beings, and one of the most important dances was an impersonation of human beings who were the ancestors of the elk.

The songs recorded at Neah Bay included the songs of the Makah Day dances, rendered by the leading singers, and songs of the "impersonation dances" that formed part of the Klokali ceremony. In these dances they formerly impersonated the wolf, deer, and wild white geese. An interesting group of Clayoquot songs was addressed to the sea when the breakers were high and it was said "the sea always seemed to become calm soon after these songs were sung." A phase of music hitherto unstudied in detail was the old composed song, distinct from the song received in a dream. It appears from data collected in two localities that physical motion was considered an aid to musical composition, some musicians composing while sitting in a swing, others while walking, and others (on the coast of British Columbia) while riding in a motor boat.

After five weeks at Neah Bay Miss Densmore went to Chilliwack, British Columbia, where Indians from a wide territory are annually employed as pickers in the hop fields. An effort was made to obtain songs of all important classes, from Indians as widely separated as possible. More than 125 songs were recorded, among the localities represented being the Nass, Skeena, Thompson, and Fraser Rivers, Port Simpson, the west coast of British Columbia and the southwest coast of Vancouver Island. The singers came from a region extending about 400 miles north and south and about 150 miles east and west. Two aged medicine men recorded songs which they use at the present time in treating the sick, and numerous healing songs were recorded by other Indians. One was for the cure of smallpox; in another the doctor addressed the seal, grizzly bear, and deer, asking their help, while the next song contained their favorable response. The medicine men appreciated the value of the work and recorded their songs without reluctance.

Mention should be made of the *slahal* game played often at the hop camp by a large number of Indians, with crowds of Indian spectators. The songs and method of playing the game were recorded, the players were photographed during a game, and the bone game implements were loaned for photographic purposes.

Seven manuscripts on the foregoing field work were submitted to the Bureau of American Ethnology with the following titles: "Songs of the Quileute Indians"; "Makah and Clayoquot songs for treating the sick and Makah songs in honor of the dead"; "Klokali songs of the Makah Indians"; "Songs of Indians living on the Sliamey and Homaco Reserves in British Columbia"; "Songs of Indians living at Port Simpson and on the Skeena and Nass Rivers in British Columbia"; "Makah and Clayoquot songs"; and "Songs and dances presented on Makah Day, 1926, at Neah Bay, Wash." A paper was also submitted entitled "A comparison between Pawnee songs and those previously analyzed," with 18 tables of analysis. The number of manuscript pages was 178 and the number of transcribed songs 124.

In British Columbia, as in the United States, opportunities for the study of genuine Indian music are rapidly passing, though there still remain old people who can sing the ancient songs.

Dr. Aleš Hrdlička, curator of physical anthropology, United States National Museum, made during the spring and summer of 1926 a comprehensive anthropological and archeological survey in Alaska.

Upon reaching the Seward Peninsula he found himself confronted with unsurmountable difficulties in the matter of transportation. The arrival of the Revenue Cutter *Bear* was a fortunate circumstance, for he secured both accommodation and promise of assistance

in his work. Doctor Hrdlička left on the *Bear* July 22 with the intention of landing where indications might demand; but notwithstanding certain disadvantages, until the end of the *Bear's* journey he did not feel justified in leaving the ship.

The trip, barring the storms, ice, etc., was propitious. The ship stopped at every place of importance along the whole coast up to Point Barrow. He was given facilities and help to make at least the most necessary observations and collections.

Scientific results.—The whole trip was very useful, and threw a definite light on a number of important problems in the regions covered. It suggested definite notions as to what is to be done in the future, among which are the following:

Antiquity of man.—Much that was seen strengthens the probabilities, as well as showing the facilities of Asiatic migrations over and along the Seward Peninsula, across Bering Sea, and also by way of the Aleutian Islands. But material evidence of these comings was not found, and must be very limited, if not completely wanting, for the following reasons: The comings could have been only by small numbers of people, and these contingents would effect but small and temporary settlements along the coasts and perhaps the banks of a few streams. The reasons were a relative scarcity of the population in the northeastern parts of Asia, on account of the limited resources of that region; the more or less nomadic habits of the people, due to seasonal conditions and the shifting food supply; their dependence on the sea and rivers for both food and movement, the hinterland being poor in resources and not favorable for migrations toward more desirable regions.

Old Eskimo sites.—Older abandoned sites of the Eskimo, from those of small camps with perhaps only two or three "igloos" to good-sized dead villages, are quite common. They occur as a rule on, or just above, the low "spits" and beaches of the sea and on the banks of the rivers or lakes.

The Teller battle field.—This consists merely of a tundra plain, dotted with small lagoons. In its vicinity are at least two, and probably more, small old sites, with their graves for the most part already assimilated by the tundra. The plain itself shows, as far as seen, nothing but moss and other similar vegetation.

The archeological objects that it was possible to secure show: (1) Contact with Asia; (2) two varieties of decoration, rectilinear and curvilinear, the latter much superior to the former; (3) extensive trading ("jade," slate, obsidian); (4) a great differentiation and variety in places, indicating a rather high culture.

This survey of conditions in the northwestern part of Alaska indicates the need of prompt work of archeological and anthropological nature in several directions.

Dr. Walter Hough, head curator of anthropology, United States National Museum, was detailed to examine recent excavations at Indian Mound, Tenn., reported by the Hon. Joseph W. Byrns. In the town of Indian Mound is a large burial mound from which the place derives its name. The mound is much lowered by cultivation, some of the older settlers affirming that it was several feet higher than at present.

Through the enterprise of Mr. T. W. Seay, jr., excavations in the summit of the mound brought to light several slab-box burials, a number of skeletons, and a few artifacts. From the surface of the mound and adjoining lots, showing rich, black soil containing artifacts, many specimens of stone implements have been picked up. Through the kindness of Mr. Seay, Doctor Hough visited a number of village sites, burial mounds, and flint quarries in the neighborhood of Indian Mound and Dover, collecting numerous specimens.

EDITORIAL WORK AND PUBLICATIONS

The editing of the publications of the bureau was continued through the year by Mr. Stanley Searles, editor, assisted by Mrs. Frances S. Nichols, editorial assistant. The status of the publications is presented in the following summary:

PUBLICATIONS ISSUED

Bulletin 82. Archeological Observations North of the Rio Colorado, by Neil M. Judd. 171 pp., 61 pls., 46 figs.

Bulletin 83. Burials of the Algonquian, Siouan, and Caddoan Tribes West of the Mississippi, by David I. Bushnell, jr. 103 pp., 37 pls., 3 figs.

List of Publications of the Bureau of American Ethnology, 46 pp.

PUBLICATIONS IN PRESS OR IN PREPARATION

Forty-first Annual Report. Accompanying papers: Coiled Basketry in British Columbia and Surrounding Region (Boas, assisted by Haeberlin, Roberts, and Teit); Two Prehistoric Villages in Middle Tennessee (Myer).

Forty-second Annual Report. Accompanying papers: Social Organization and Social Usages of the Indians of the Creek Confederacy; Religious Beliefs and Medical Practices of the Creek Indians; Aboriginal Culture of the Southeast (Swanton); Indian Trails of the Southeast (Myer).

Forty-third Annual Report. Accompanying papers: The Osage Tribe; Two Versions of the Child-naming Rite (La Flesche); Wawenock Myth Texts from Maine (Speck); Native Tribes and Dialects of Connecticut (Speck); Picuris Children's Stories, with Texts and Songs (Harrington); Iroquoian Cosmology—Part II (Hewitt).

Forty-fourth Annual Report. Accompanying papers: Excavation of the Burton Mound at Santa Barbara, Calif. (Harrington); Social and Religious Usages of the Chickasaw Indians (Swanton); Uses of Plants by the Chippewa Indians (Densmore); Archeological Investigations—II (Fowke).

Bulletin 84. A Vocabulary of the Kiowa Language (Harrington).

Bulletin 85. Contributions to Fox Ethnology (Michelson).

Bulletin 86. Chippewa Customs (Densmore).

DISTRIBUTION OF PUBLICATIONS

The distribution of the publications of the bureau has been continued under the immediate charge of Miss Helen Munroe, assisted by Miss Emma B. Powers. Publications were distributed as follows:

Report volumes and separates	1,474
Bulletins and separates	7,289
Contributions to North American Ethnology	34
Miscellaneous publications	1,914

As compared with the fiscal year ending June 30, 1926, there was a decrease of 3,079 publications distributed. This was partly due to the fact that one less publication was distributed to the mailing list than in the previous year.

Six addresses were added to the mailing list during the year and 31 taken from the list, making a net decrease of 25. The list now stands at 1,713.

ILLUSTRATIONS

Following is a summary of work accomplished in the illustration branch of the bureau under the supervision of Mr. DeLancey Gill, illustrator:

Illustrations: Photographs retouched and lettered, drawings, etc., prepared and made ready for engraving	647
Drawings made, maps, diagrams, etc	44
Illustrations, engraver's proof criticized	516
Colored illustration proofs examined at Government Printing Office	10,500
Photographic prints of archeologic and ethnologic subjects	603
Negatives made	72
Lantern slides	16
Photographic enlargements	6
Film rolls developed from field exposures	24

About 70 per cent of the photographic laboratory work for the bureau was done by Dr. A. J. Olmsted, of the United States National Museum; and 50 per cent of the illustration work by Mr. Gill was for the publications of the various bureaus of the Smithsonian in cooperation. This arrangement has proved eminently satisfactory in the past year, with a substantial saving of more than 80 per cent of the former cost.

LIBRARY

The reference library has continued under the immediate care of Miss Ella Leary, librarian, assisted by Mr. Thomas Blackwell. The library consists of 27,141 volumes, about 15,937 pamphlets, and several thousand unbound periodicals. During the year 480 books were accessioned, of which 83 were acquired by purchase and 397 by gift and exchange; also 3,950 serials, chiefly the publications of learned societies, were received and recorded, of which only 102 were ob-

tained by purchase, the remainder being received through exchange. Of pamphlets, 225 were obtained. During the year 288 volumes were sent to the bindery. The catalogue was increased by the addition of 1,980 cards. A considerable amount of time was given to preparing bibliographic lists for correspondents. The endeavor to supply deficiencies in the sets of publications of institutions of learning was continued without remission. Requisition was made on the Library of Congress during the year for an aggregate of 300 volumes for official use. The Bureau library was frequently consulted by officers of other Government establishments.

COLLECTIONS

92528. Collection of archeological and skeletal material (740 specimens) secured along the Upper Columbia River, Washington, during the spring of 1926 by Herbert W. Krieger.

92528. Skeleton of a shaman (less the skull), 2 femora of another shaman, and 2 bleached bones from the skeleton of a chief, all Tlinkit, of Alaska, collected by Dr. A. Hrdlička.

94202. Small collection of shell beads and bracelets, and stone implements, obtained from the ruin of Las Trincheras in the Altar districts of Sonora by S. A. Williams.

94776. Archeological specimens from Arkansas, Colorado, Florida, Kentucky, and Tennessee, secured by various collectors for the bureau. (25 specimens.)

93522. Anthropological, geological, and biological material collected by Dr. Aleš Hrdlička in Alaska during the summer of 1926. (1,374 specimens.)

93607. Material collected during the summer of 1926 in Louisiana and Mississippi by Henry B. Collins, jr. (236 specimens.)

95011. Ten master records of Hopi Indian songs recorded during the summer of 1926 at the Grand Canyon by Dr. J. Walter Fewkes and two master records of a speech by William Jennings Bryan.

95372. One carved and painted wooden figure representing a Hopi snake priest.

96091. Four Indian crania from Elden Pueblo, Ariz., and 2 from Montezuma Canyon, Colo.

96920. Collection of archeological objects gathered for the bureau at Indian Mound, Tenn., by Dr. Walter Hough.

96921. Archeological material collected for the bureau at Elden Pueblo, Ariz., by Dr. J. Walter Fewkes during the summer of 1926.

PROPERTY

Office equipment was purchased to the amount of $123.74.

MISCELLANEOUS

Clerical.—The correspondence and other clerical work of the office has been conducted by Miss May S. Clark, clerk to the chief, assisted by Mr. Anthony W. Wilding, stenographer. Miss Mae W. Tucker, stenographer, continued to assist Dr. John R. Swanton in compiling

a Timucua dictionary and Mr. Hewitt in finishing the reclassifying and cataloguing of the manuscripts in the bureau archives. Miss Tucker was also engaged in classifying and cataloguing the musical records in the possession of the bureau. Mrs. Frances S. Nichols assisted the editor.

Personnel.—Dr. F. H. H. Roberts, jr., archeologist, was appointed on the staff of the bureau November 1, 1926.

Respectfully submitted.

J. Walter Fewkes,
Chief, Bureau of American Ethnology.

Dr. C. G. Abbot,
Acting Secretary, Smithsonian Institution.

APPENDIX 5

REPORT ON THE INTERNATIONAL EXCHANGES

SIR: I have the honor to submit the following report on the operations of the International Exchange Service during the fiscal year ending June 30, 1927:

The congressional appropriation allowed for the support of the system of international exchanges conducted under the direction of the Smithsonian Institution during the fiscal year 1927 was $46,260, the same as for the year 1926. In addition, $300 was allotted for printing and binding. The collections on account of repayments from governmental and other establishments amounted to $5,947.24, making the total available resources for carrying on the service during the year, $52,507.24.

The total number of packages handled was 590,879, an increase of 110,103 over the previous year. This is the largest increase in the number of packages handled during any one year since the organization of the service in 1850. Leaving out the period during and immediately after the close of the World War—when the number of packages handled fluctuated greatly owing to the suspension and resumption of shipments to certain countries—the other years in which there were unusually large increases in the number of packages passing through the service were 1909 (increase 25,777 packages), 1912 (increase 29,794 packages), and 1913 (increase 23,129 packages). The packages handled during the fiscal year 1927 weighed a total of 553,125 pounds, a decrease of 5,368 pounds.

The large number of packages handled during 1927 was in great measure due to the action of the United States Department of Agriculture in turning over to the exchange office many hundreds of small packages for distribution abroad that it formerly sent to their destinations by mail. That department toward the close of the fiscal year discontinued sending this material to the Institution and resumed its transmission by mail.

For statistical purposes the packages handled by the exchange service are divided into several classes. The number and weight of the packages in these classes are given in the following table:

	Packages		Weight	
	Sent	Received	Sent	Received
			Pounds	*Pounds*
United States parliamentary documents sent abroad	220,506		94,955	
Publications received in return for parliamentary documents		6,778		23,020
United States departmental documents sent abroad	219,131		152,078	
Publications received in return for departmental documents		5,646		23,940
Miscellaneous scientific and literary publications sent abroad	106,786		182,036	
Miscellaneous scientific and literary publications received from abroad for distribution in the United States		32,032		77,096
Total	546,423	44,456	429,069	124,056
Grand total	590,879		553,125	

Last year 43,783 packages were received from abroad, a substantial gain over the previous year in the number of packages received from foreign countries. During the past 12 months, as shown in the above table, there was a further gain in the number of packages received from abroad.

Mr. Vittorio Benedetti, chief of the Italian exchange office in Rome for the past 13 years, severed his connection with that office on June 30, 1926, and was succeeded by Dr. Guglielmo Passigli, who is one of the librarians of the Victor Emanuel National Library, under the direction of which the Italian exchange office is conducted. Dr. Passigli has been succeeded since by Dr. Vincenzo Fago as director of the Italian exchange office. The Institution desires to record here its appreciation of the valuable services rendered the Smithsonian by Mr. Benedetti, not only in his regular duties as chief of the exchange office, but in his painstaking efforts to procure copies of Italian official publications for the Library of Congress in exchange for the full series of United States governmental documents sent to Italy. To what extent the services of Mr. Benedetti were valued by correspondents in his own country may be inferred from the following extract from a letter addressed to Mr. Benedetti by an official of the Library of American Studies in Italy:

> It is with keen regret that I learn that you have left the exchange office where for so many years you have rendered such courteous and efficient service in promoting close intellectual relations between Italy and other countries. The Library of American Studies found in you a sincere friend and your counsel was most helpful to us when our organization was in its formative period.

Mr. Benedetti's interest in the exchange service at large was so great that shortly after his appointment as chief of the Italian Office of International Exchanges he made a study of the origin and development of the exchanges and wrote an account thereof, a copy of the manuscript of which he presented to the Institution. So far as

this office is aware, the work was not published, although it contains much valuable information concerning the exchange service in general, giving special attention to the Italian exchanges.

The officials of many other exchange bureaus likewise are rendering great service to the cause of science and learning through their long connection with the exchange service and their devotion to the work of the diffusion of knowledge among men.

Although the Smithsonian Institution can not undertake to obtain copies of all publications desired by the large number of correspondents making use of the service, it endeavors to meet these requests as far as it is practicable. It is desirable, however, that correspondents themselves take steps to make application for publications they desire whenever it is possible to do so. Among the requests made during the year for assistance in obtaining books was one received through the Austrian Exchange Agency from the botanical department of the Natural History Museum in Vienna for certain American publications bearing on botany. The Institution brought the request to the attention of the proper organizations, and although only a part of the publications desired were received, the director of the botanical department expressed his great appreciation of the action taken by the Institution in the matter.

The total number of boxes required in dispatching exchange consignments abroad during the year was 2,608, an increase of 87 over the number for the preceding year.

Prior to 1926 it was the practice of the Institution to forward the full series of official documents to depositories at quarterly intervals. In April of that year that practice was discontinued, and shipments to the depositories have since been made about once a month. This change, as was stated in my last report, was made in order to comply with the request of several depositories that steps be taken to have the publications forming the regular series of governmental documents delivered more promptly, so that the information contained therein would be available for use as shortly after publication as practicable. These frequent shipments account for the increase of 230 in the number of boxes sent to the depositories—619 in 1927 as compared with 389 in 1926.

It is the usual custom of the Institution to send exchange packages to foreign distributing agencies in boxes by freight. However, in cases where the packages that accumulate for a particular country are not of sufficient bulk to warrant their transmission in that manner, they are mailed directly to their destinations without passing through the foreign agencies. Packages bearing addresses in remote places which can not be reached through existing exchange bureaus also are forwarded by mail. The number of packages mailed in 1927 was 62,432—an increase of 13,345 over the number

posted during the previous year. The forwarding of this large number of packages by mail required an expenditure for postage during the year of $3,000.

The number of boxes sent to each country during the fiscal year 1927 is given in the following table:

Consignments of exchanges forwarded to foreign countries

Country	Number of boxes	Country	Number of boxes
Argentina	57	Mexico	11
Austria	54	Netherlands	77
Belgium	65	New South Wales	33
Brazil	38	New Zealand	19
British colonies	18	Norway	49
Canada	44	Palestine	33
Chile	23	Peru	21
China	58	Poland	42
Colombia	22	Portugal	25
Costa Rica	18	Queensland	22
Cuba	11	Rumania	13
Czechoslovakia	64	Russia	139
Danzig	5	South Australia	23
Denmark	52	Spain	37
Egypt	2	Sweden	78
Estonia	20	Switzerland	72
Finland	10	Tasmania	19
France	184	Union of South Africa	36
Germany	352	Uruguay	21
Great Britain and Ireland	326	Venezuela	19
Greece	21	Victoria	50
Hungary	40	Western Australia	25
India	57	Yugoslavia	17
Italy	103		
Japan	82	Total	2,608
Lithuania	1		

FOREIGN DEPOSITORIES OF UNITED STATES GOVERNMENTAL DOCUMENTS

In accordance with the terms of the convention concluded at Brussels in March, 1886, and under authority granted by Congress in resolutions approved March 2, 1867, March 2, 1901, and March 3, 1925, there are now forwarded abroad to certain designated depositories 103 sets of United States governmental documents—60 of which are full and 43 partial sets. This is an increase of two during the past fiscal year, partial sets being sent to Lithuania and to the State of Minas Geraes, Brazil.

Information was received during the year that China and Egypt had adhered to both of the Brussels exchange conventions. Since 1908 a full set of governmental documents has been sent to the American Chinese Publication Exchange Department of the Shanghai Bureau of Foreign Affairs. When China joined the convention it requested that the depository be changed to the Metropolitan Library in Peking.

Since 1905 a partial set of governmental documents has been forwarded to Egypt, but now that that country has become a party to the convention, the set has been increased to a full one. The depository formerly was the Royal Library, but, at the request of the Egyptian Government, it has been changed to the Bureau of Publications of the Ministry of Finances.

At the request of the New Zealand depository—the General Assembly Library—the full set of governmental documents that had been forwarded to that country since 1876 was changed last year to a partial set. In compliance with a later request, the depository has again been listed to receive a full set.

A list of the foreign depositories is given below:

DEPOSITORIES OF FULL SETS

Argentina: Ministerio de Relaciones Exteriores, Buenos Aires.
  Buenos Aires: Biblioteca de la Universidad Nacional de La Plata, La Plata. (Depository of the Province of Buenos Aires.)
Australia: Library of the Commonwealth Parliament, Canberra.
  New South Wales: Public Library of New South Wales, Sydney.
  Queensland: Parliamentary Library, Brisbane.
  South Australia: Parliamentary Library, Adelaide.
  Tasmania: Parliamentary Library, Hobart.
  Victoria: Public Library of Victoria, Melbourne.
  Western Australia: Public Library of Western Australia, Perth.
Austria: Bundesamt für Statistik, Schwarzenbergstrasse 5, Vienna I.
Belgium: Bibliothèque Royale, Brussels.
Brazil: Bibliotheca Nacional, Rio de Janeiro.
Canada: Library of Parliament, Ottawa.
  Manitoba: Provincial Library, Winnipeg.
  Ontario: Legislative Library, Toronto.
  Quebec: Library of the Legislature of the Province of Quebec, Quebec.
Chile: Biblioteca del Congreso Nacional, Santiago.
China: Metropolitan Library, Pei Hai, Peking.
Colombia: Biblioteca Nacional, Bogotá.
Costa Rica: Oficina de Depósito y Canje Internacional de Publicaciones, San José.
Cuba: Secretaría de Estado (Asuntos Generales y Canje Internacional), Habana.
Czechoslovakia: Bibliothèque de l'Assemblée Nationale, Prague.
Denmark: Kongelige Bibliotheket, Copenhagen.
Egypt: Bureau des Publications, Ministère des Finances, Cairo.
Estonia: Riigiraamatukogu (State Library), Reval.
France: Bibliothèque Nationale, Paris.
  Paris: Préfecture de la Seine.
Germany: Deutsche Reichstags-Bibliothek, Berlin.
  Baden: Universitäts-Bibliothek, Freiburg. (Depository of the State of Baden.)
  Bavaria: Staats-Bibliothek, Munich.
  Prussia: Preussische Staatsbibliothek, Berlin, N. W. 7.
  Saxony: Sächsische Landesbibliothek, Dresden—N. 6.
  Wurttemberg: Landesbibliothek, Stuttgart.

GREAT BRITAIN:

ENGLAND: British Museum, London.

GLASGOW: City Librarian, Mitchell Library, Glasgow.

LONDON: London School of Economics and Political Science. (Depository of the London County Council.)

GREECE: Bibliothèque Nationale, Athens.

HUNGARY: Hungarian House of Delegates, Budapest.

INDIA: Imperial Library, Calcutta.

IRISH FREE STATE: National Library of Ireland, Dublin.

ITALY: Biblioteca Nazionale Vittorio Emanuele, Rome.

JAPAN: Imperial Library of Japan, Tokyo.

MEXICO: Biblioteca Nacional, Mexico, D. F.

NETHERLANDS: Bibliotheek van de Tweede Kamer der Staten-Generaal, The Hague.

NEW ZEALAND: General Assembly Library, Wellington.

NORTHERN IRELAND: Ministry of Finance, Belfast.

NORWAY: Universitets-Bibliotek, Oslo. (Depository of the Government of Norway.)

PERU: Biblioteca Nacional, Lima.

POLAND: Bibliothèque du Ministère des Affaires Étrangères, Warsaw.

PORTUGAL: Bibliotheca Nacional, Lisbon.

RUSSIA: Shipments temporarily suspended.

SPAIN: Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultativo de Archiveros, Bibliotecarios y Arqueólogos, Madrid.

SWEDEN: Kungliga Biblioteket, Stockholm.

SWITZERLAND: Bibliothèque Centrale Fédérale, Berne.

SWITZERLAND: Library of the League of Nations, Geneva.

TURKEY: Shipments temporarily suspended.

UNION OF SOUTH AFRICA: State Library, Pretoria, Transvaal.

URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.

VENEZUELA: Biblioteca Nacional, Caracas.

YUGOSLAVIA: Ministère des Affaires Étrangères, Belgrade.

DEPOSITORIES OF PARTIAL SETS

AUSTRIA:

VIENNA: Magistrat der Stadt.

BOLIVIA: Ministerio de Colonización y Agricultura, La Paz.

BRAZIL:

MINAS GERAES: Directoria Geral de Estatistica em Minas, Bello Horizonte, Minas Geraes.

RIO DE JANEIRO: Bibliotheca da Assemblea Legislativa do Estado, Nictheroy.

CANADA:

ALBERTA: Provincial Library, Edmonton.

BRITISH COLUMBIA: Legislative Library, Victoria.

NEW BRUNSWICK: Legislative Library, Fredericton.

NOVA SCOTIA: Provincial Secretary of Nova Scotia, Halifax.

PRINCE EDWARD ISLAND: Legislative Library, Charlottetown.

SASKATCHEWAN: Government Library, Regina.

BRITISH GUIANA: Government Secretary's Office, Georgetown, Demerara.

BULGARIA: Ministère des Affaires Étrangères, Sofia.

CEYLON: Colonial Secretary's Office (Record Department of the Library), Colombo.

DANZIG: Stadtbibliothek, Free City of Danzig.

DOMINICAN REPUBLIC: Biblioteca del Senado, Santo Domingo.

ECUADOR: Biblioteca Nacional, Quito.
FINLAND: Parliamentary Library, Helsingfors.
FRANCE:
ALSACE-LORRAINE: Bibliothèque Universitaire et Régionale de Strasbourg, Strasbourg.
GERMANY:
BREMEN: Senatskommission für Reichs- und Auswärtige Angelegenheiten.
HAMBURG: Senatskommission für die Reichs- und Auswärtigen Angelegenheiten.
HESSE: Landesbibliothek, Darmstadt.
LÜBECK: President of the Senate.
THURINGIA: Rothenberg-Bibliothek, Landesuniversität, Jena.
GUATEMALA: Secretary of the Government, Guatemala.
HAITI: Secrétaire d'Etat des Relations Extérieures, Port au Prince.
HONDURAS: Secretary of the Government, Tegucigalpa.
ICELAND: National Library, Reykjavik.
INDIA:
MADRAS: Chief Secretary to the Government of Madras, Public Department, Madras.
UNITED PROVINCES OF AGRA AND OUDH: University of Allahabad, Allahabad.
JAMAICA: Colonial Secretary, Kingston.
LATVIA: Bibliothèque d'Etat, Riga.
LIBERIA: Department of State, Monrovia.
LITHUANIA: Ministère des Affaires Étrangères, Kovno.
LOURENÇO MARQUEZ: Government Library, Lourenço Marquez.
MALTA: Minister for the Treasury, Valetta.
NEWFOUNDLAND: Colonial Secretary, St. John's.
NICARAGUA: Superintendente de Archivos Nacionales, Managua.
PANAMA: Secretaría de Relaciones Exteriores, Panama.
PARAGUAY: Sección Canje Internacional de Publicaciones del Ministerio de Relaciones Exteriores, Estrella 563, Asunción.
RUMANIA: Academia Romana, Bucharest.
SALVADOR: Ministerio de Relaciones Exteriores, San Salvador.
SIAM: Department of Foreign Affairs, Bangkok.
STRAITS SETTLEMENTS: Colonial Secretary, Singapore.

INTERPARLIAMENTARY EXCHANGE OF OFFICIAL JOURNAL

During the past fiscal year 24 new foreign depositories were added to the list of those receiving the daily issue of the Congressional Record. The new depositories are located in the following places: Brazil—States of Amazonas, Espirito Santo, São Paulo, São Salvador; Egypt; Germany—States of Mecklenburg-Schwerin, Mecklenburg-Strelitz, Schaumburg-Lippe; Gibraltar; Iraq; Mexico—States of Campeche, Chiapas, Guanajuato, Querétaro, Mexico, Michoacán, Morelos, Nayarit, Oaxaca, Puebla, Tlaxcala; Spain—Province of Barcelona; Syria—State of Alaouites, and République Libanaise.

The total number of copies of the daily issue of the Congressional Record now forwarded abroad through the Institution is 99. A complete list of the States taking part in this exchange, together with the

names of the establishments to which the Record is mailed, is given below:

DEPOSITORIES OF CONGRESSIONAL RECORD

ARGENTINA:

Biblioteca del Congreso Nacional, Buenos Aires.

Cámara de Diputados, Oficina de Información Parlamentaria, Buenos Aires.

Buenos Aires: Biblioteca del Senado de la Provincia de Buenos Aires, La Plata.

AUSTRALIA:

Library of the Commonwealth Parliament, Canberra.

New South Wales: Library of Parliament of New South Wales, Sydney.

Queensland: Chief Secretary's Office, Brisbane.

Western Australia: Library of Parliament of Western Australia, Perth.

AUSTRIA: Bibliothek des Nationalrates, Vienna I.

BELGIUM: Bibliothèque de la Chambre des Représentants, Brussels.

BOLIVIA: Cámara de Diputados, Congreso Nacional, La Paz.

BRAZIL:

Bibliotheca do Congresso Nacional, Rio de Janeiro.

Amazonas: Archivo, Bibliotheca e Imprensa Publica, Manáos.

Espirito Santo: Presidencia do Estado do Espirito Santo, Victoria.

São Paulo: Bibliotheca Publica do Estado de São Paulo, São Paulo.

São Salvador: Governador do Estado de Bahia, São Salvador.

CANADA:

Library of Parliament, Ottawa.

Clerk of the Senate, Houses of Parliament, Ottawa.

CHINA: Metropolitan Library, Pei Hai, Peking.

COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.

CUBA:

Biblioteca de la Cámara de Representantes, Habana.

Biblioteca del Senado, Habana.

CZECHOSLOVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.

DANZIG: Stadtbibliothek, Danzig.

DENMARK: Rigsdagens Bureau, Copenhagen.

DOMINICAN REPUBLIC: Biblioteca del Senado, Santo Domingo.

DUTCH EAST INDIES: Volksraad van Nederlandsch-Indie, Batavia, Java.

EGYPT: Bureau des Publications, Ministère des Finances, Cairo.

ESTONIA: Rigiraamatukogu (State Library), Reval.

FRANCE:

Bibliothèque de la Chambre des Députés, au Palais Bourbon, Paris.

Bibliothèque du Sénat, au Palais du Luxembourg, Paris.

GERMANY:

Deutsche Reichstags-Bibliothek, Berlin, N. W. 7.

Anhalt: Anhaltische Landesbücherei, Dessau.

Baden: Universitäts-Bibliothek, Heidelberg.

Braunschweig: Bibliothek des Braunschweigischen Staatsministeriums, Braunschweig.

Mecklenburg-Schwerin: Staatsministerium, Schwerin.

Mecklenburg-Strelitz: Finanzdepartement des Staatsministeriums, Neustrelitz.

Oldenburg: Oldenburgisches Staatsministerium, Oldenburg i. O.

Prussia: Bibliothek des Abgeordnetenhauses, Prinz-Albrechtstrasse 5, Berlin, S. W. 11.

Schaumburg-Lippe: Schaumburg-Lippische Landesregierung, Bücheburg.

GIBRALTAR: Gibraltar Garrison Library Committee, Gibraltar.
GREAT BRITAIN: Library of the Foreign Office, London.
GREECE: Library of Parliament, Athens.
GUATEMALA: Archivo General del Gobierno, Guatemala.
HAITI: Secrétaire d'Etat des Relations Extérieures, Port-au-Prince.
HONDURAS: Biblioteca del Congreso Nacional, Tegucigalpa.
HUNGARY: Bibliothek des Abgeordnetenhauses, Budapest.
INDIA: Legislative Department, Simla.
ITALY:
 Biblioteca del Senato del Regno, Rome.
 Biblioteca della Camera dei Deputati, Rome.
IRAQ: Chamber of Deputies, Baghdad, Iraq (Mesopotamia).
LATVIA: Library of the Saeima, Riga.
LIBERIA: Department of State, Monrovia.
MEXICO: Mexico, Secretaria de la Cámara de Diputados, Mexico, D. F.
 Aguascalientes: Gobernador del Estado de Aguascalientes, Aguascalientes.
 Campeche: Gobernador del Estado de Campeche, Campeche.
 Chihuahua: Gobernador del Estado de Chihuahua, Chihuahua.
 Chiapas: Gobernador del Estado de Chiapas, Tuxtla Gutierrez.
 Coahuila: Periódico Oficial del Estado de Coahuila, Palacio de Gobierno, Saltillo.
 Colima: Gobernador del Estado de Colima, Colima.
 Durango: Gobernador Constitucional del Estado de Durango, Durango.
 Guanajuato: Secretaría General de Gobierno del Estado, Guanajuato.
 Guerrero: Gobernador del Estado de Guerrero, Chilpancingo.
 Jalisco: Biblioteca del Estado, Guadalajara.
 Lower California: Gobernador del Distrito Norte, Mexicali, B. C., Mexico.
 Mexico: Gaceta del Gobierno, Toluca, Mexico.
 Michoacán: Secretaría General de Gobierno del Estado de Michoacán, Morelia.
 Morelos: Palacio de Gobierno, Cuernavaca.
 Nayarit: Gobernador de Nayarit, Tepic.
 Nuevo León: Biblioteca del Estado, Monterey.
 Oaxaca: Periódico Oficial, Palacio de Gobierno, Oaxaca.
 Puebla: Secretario General de Gobierno, Zaragoza.
 Queretaro: Secretaría General de Gobierno, Sección de Archivo, Queretaro.
 San Luis Potosi: Congreso del Estado, San Luis Potosi.
 Sinaloa: Gobernador del Estado de Sinaloa, Culiacan.
 Sonora: Gobernador del Estado de Sonora, Hermosillo.
 Tabasco: Secretaría General de Gobierno, Sección 3a, Ramo de Prensa, Villahermosa.
 Tamaulipas: Secretaria General de Gobierno, Victoria.
 Tlaxcala: Secretaría de Gobierno del Estado, Tlaxcala.
 Vera Cruz: Gobernador del Estado de Vera Cruz, Departamento de Gobernación y Justicia, Jalapa.
 Yucatán: Gobernador del Estado de Yucatán, Mérida, Yucatán.
NEW ZEALAND: General Assembly Library, Wellington.
PERU: Cámara de Diputados, Congreso Nacional, Lima.
NORWAY: Storthingets Bibliothek, Oslo.
POLAND: Ministère des Affaires Étrangères, Warsaw.
PORTUGAL: Bibliotheca do Congresso da Republica, Lisbon.
RUMANIA:
 Bibliothèque de la Chambre des Députés, Bucharest.
 Ministère des Affaires Étrangères, Bucharest.

SPAIN:

Biblioteca del Senado, Madrid.

Biblioteca del Congreso de los Diputados, Madrid.

Barcelona: Biblioteca de la Comisión Permanente Provincial de Barcelona, Barcelona.

SWITZERLAND:

Bibliothèque de l'Assemblée Fédérale Suisse, Berne.

Library of the League of Nations, Geneva.

SYRIA:

Ministère des Finances de la République Libanaise, Service du Matériel, Beirut.

Governor of the State of Alaouites, Lattaquié.

UNION OF SOUTH AFRICA:

Library of Parliament, Cape Town, Cape of Good Hope.

State Library, Pretoria, Transvaal.

URUGUAY: Biblioteca de la Cámara de Representantes, Montevideo.

VENEZUELA: Cámara de Diputados, Congreso Nacional, Carácas.

YUGOSLAVIA: Library of the Skupshtina, Belgrade.

FOREIGN EXCHANGE AGENCIES

Egypt having joined the Brussels Exchange Convention, as previously stated in this report, the Egyptian Government, in compliance with the stipulations set forth in Article I of the convention, established the Bureau of Publications in the Ministry of Finances at Cairo to act as the exchange agency for that country.

The exchange bureau in Yugoslavia was changed during the year from the Royal Serbian Academy to the Ministry of Foreign Affairs at Belgrade.

The Dutch Central Scientific Bureau, which acts as the exchange agency for the Netherlands, has been conducted under the direction of various scientific organizations, the bureau being since January, 1920, under the Library of the Technical Academy at Delft. The Dutch Government has now made the Central Scientific Bureau a subdivision of the Federal organization, and has placed it under the Royal Library at The Hague, the transfer to take place on January 1, 1928.

A complete list of the foreign exchange agencies or bureaus is given below. Those agencies in the larger countries and many of those in the smaller countries forward consignments to the Smithsonian Institution for distribution in the United States. Correspondents desiring to make use of any of the exchange agencies in the transmission of packages to the United States should first communicate with the respective bureau in order to ascertain whether the bureau sends consignments to this country.

LIST OF EXCHANGE AGENCIES

ALGERIA, via France.

ANGOLA, via Portugal.

ARGENTINA: Comisión Protectora de Bibliotecas Populares, Calle Córdoba 931, Buenos Aires.

AUSTRIA: Bundesamt für Statistik, Schwarzenbergstrasse 5, Vienna I.
AZORES, via Portugal.
BELGIUM: Service Belge des Échanges Internationaux, Rues des Longs-Chariots, 46, Brussels.
BOLIVIA: Oficina Nacional de Estadistica, La Paz.
BRAZIL: Servicio de Permutações Internacionaes, Bibliotheca Nacional, Rio de Janeiro.
BRITISH COLONIES: Crown Agents for the Colonies, London.
BRITISH GUIANA: Royal Agricultural and Commercial Society, Georgetown.
BRITISH HONDURAS: Colonial Secretary, Belize.
BULGARIA: Institutions Scientifiques de S. M. le Roi de Bulgarie, Sofia.
CANARY ISLANDS, via Spain.
CHILE: Servicio de Canjes Internacionales, Biblioteca Nacional, Santiago.
CHINA: Bureau of International Exchange of Publications, Ministry of Education, Peking.
COLOMBIA: Oficina de Canjes Internacionales y Reparto, Biblioteca Nacional, Bogotá.
COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.
CZECHOSLOVAKIA: Service Tchécoslovaque des Échanges Internationaux, Bibliothèque de l'Assemblée Nationale, Prague 1-79.
DANZIG: Amt für den Internationalen Schriftenaustausch der Freien Stadt Danzig, Stadtbibliothek, Danzig.
DENMARK: Kongelige Danske Videnskabernes Selskab, Copenhagen.
DUTCH GUIANA: Surinaamsche Koloniale Bibliotheek, Paramaribo.
ECUADOR: Ministerio de Relaciones Exteriores, Quito.
EGYPT: Bureau des Publications, Ministère des Finances, Cairo.
ESTONIA: Riigiraamatukogu (State Library), Reval.
FINLAND: Delegation of the Scientific Societies of Finland, Helsingfors.
FRANCE: Service Français des Échanges Internationaux, 110 Rue de Grenelle, Paris.
GERMANY: Amerika-Institut, Universitätstrasse 8, Berlin, N. W. 7.
GREAT BRITAIN AND IRELAND: Messrs. Wheldon & Wesley, 2, 3, and 4 Arthur St., New Oxford St., London W. C. 2.
GREECE: Bibliothèque Nationale, Athens.
GREENLAND, via Denmark.
GUATEMALA: Instituto Nacional de Varones, Guatemala.
HAITI: Secrétaire d'État des Relations Extérieures, Port-au-Prince.
HONDURAS: Biblioteca Nacional, Tegucigalpa.
HUNGARY: Service Hongrois des Échanges Internationaux, Musée National Budapest, VIII.
ICELAND, via Denmark.
INDIA: Superintendent of Stationery, Bombay.
ITALY: Ufficio degli Scambi Internazionali, Biblioteca Nazionale Vittorio Emanuele, Rome.
JAMAICA: Institute of Jamaica, Kingston.
JAPAN: Imperial Library of Japan, Tokyo.
JAVA, via Netherlands.
KOREA: Government General, Seoul.
LATVIA: Service des Échanges Internationaux, Bibliothèque d'Etat de Lettonie, Riga.
LIBERIA: Bureau of Exchanges, Department of State, Monrovia.
LITHUANIA: Sent by mail.
LOURENÇO MARQUEZ, via Portugal.

Luxemburg, via Belgium.
Madagascar, via France.
Madeira, via Portugal.
Mozambique, via Portugal.
Netherlands: Bureau Scientifique Central Néerlandais, Bibliothèque de l'Académie Technique, Delft. (Beginning January 1, 1928, this bureau will be under the Royal Library at the Hague.)
New South Wales: Public Library of New South Wales, Sydney.
New Zealand: Dominion Museum, Wellington.
Nicaragua: Ministerio de Relaciones Exteriores, Managua.
Norway: Universitets-Bibliotek, Oslo.
Palestine: Hebrew University Library, Jerusalem.
Panama: Sent by mail.
Paraguay: Sección Canje Internacional de Publicaciones del Ministerio de Relaciones Exteriores, Estrella 563, Asunción.
Peru: Oficina de Reparto, Depósito y Canje Internacional de Publicaciones, Ministerio de Fomento, Lima.
Poland: Service Polonais des Échanges Internationaux, Bibliothèque du Ministère des Affaires Étrangères, Warsaw.
Portugal: Secção de Trocas Internacionaes, Bibliotheca Nacional, Lisbon.
Queensland: Bureau of Exchanges of International Publications, Chief Secretary's Department, Brisbane.
Rumania: Bureau des Échanges Internationaux, Institut Météorologique Central, Bucharest.
Russia: Academy of Sciences, Leningrad.
Salvador: Ministerio de Relaciones Exteriores, San Salvador.
Siam: Department of Foreign Affairs, Bangkok.
South Australia: Public Library of South Australia, Adelaide.
Spain: Servicio del Cambio Internacional de Publicaciones, Cuerpo Facultativo de Archiveros, Bibliotecarios y Arqueólogos, Madrid.
Sumatra, via Netherlands.
Sweden: Kongliga Svenska Vetenskaps Akademien, Stockholm.
Switzerland: Service Suisse des Échanges Internationaux, Bibliothèque Centrale Fédérale, Berne.
Syria: American University of Beirut.
Tasmania: Secretary to the Premier, Hobart.
Trinidad: Royal Victoria Institute of Trinidad and Tobago, Port-of-Spain.
Tunis, via France.
Turkey: Robert College, Constantinople.
Union of South Africa: Government Printing Works, Pretoria, Transvaal.
Uruguay: Oficina de Canje Internacional de Publicaciones, Montevideo.
Venezuela: Biblioteca Nacional, Carácas.
Victoria: Public Library of Victoria, Melbourne.
Western Australia: Public Library of Western Australia, Perth.
Yugoslavia: Ministère des Affaires Étrangères, Belgrade.

Respectfully submitted.

C. G. Abbot,
Assistant Secretary,
In Charge of Library and Exchanges.

To the Acting Secretary,
Smithsonian Institution.

APPENDIX 6

REPORT ON THE NATIONAL ZOOLOGICAL PARK

SIR: I have the honor to submit the following report on the operations of the National Zoological Park for the fiscal year ending June 30, 1927:

The appropriation made by Congress for the regular maintenance of the park was $173,199 and there was the usual allotment of $300 for printing and binding. Of this $124,330 was expended for salaries and labor in connection with the maintenance of the park, and $28,200 for the purchase of food for the animals.

The collection of animals on exhibition has been considerably increased this year by gifts, purchases, and through original collections made on the Smithsonian-Chrysler Expedition.

ACCESSIONS

There were added to the park by gift or deposit 180 specimens from 99 different donors.

Notable among these is the pigmy hippopotamus presented by Mr. Harvey S. Firestone, of Akron, Ohio, to President Coolidge, and a fine pair of South African lion cubs, presented to the President by the mayor and citizens of Johannesburg, South Africa, and deposited in the national collection. The pigmy hippopotamus is the first of the species ever to be exhibited in the park and the lions fill the long-felt want for new blood in the lion collection. Mr. Victor Evans deposited a splendid specimen of the great anteater which is doing remarkably well.

Mr. J. Delacour, of Clères, France, the noted French aviculturist who visited the National Zoological Park on a trip made through the States, presented to the collection a male of the very rare Edward's pheasant.

The largest addition to the collection ever made at one time was collected and brought to Washington by the Smithsonian-Chrysler expedition to Tanganyika Territory. This expedition was made possible through the generosity of Mr. Walter Chrysler, the automobile manufacturer, who presented the Smithsonian Institution with funds for the work. The party consisted of Dr. W. M. Mann; Mr. Arthur Loveridge, of the Museum of Comparative Zoölogy, at Cambridge; Mr. Stephen Haweis and Mr. F. G. Carnochan, of New York City. The latter two were volunteer workers, and in addition Mr. Carnochan paid his own expenses to and from Africa.

The Pathé Review sent with the party Mr. Charles Charlton to make a pictorial chronicle of the work of the expedition. The trip lasted from March to October, and four months were spent in the field collecting animals.

Before starting, a number of take-down crates for the carriage of larger animals were made at the shops in the park, under the direction of Mr. W. H. Blackburne. These proved invaluable in the field. The United States Marine Corps supplied part of the field supplies and the Freedmen's Hospital the necessary medicines.

On arrival at Dar-es-Salaam, His Excellency Sir Donald Cameron, Governor of Tanganyika, presented a license for the collection of animals and gave instructions to various civil officers to assist the party in its work. In the field the expedition engaged Mr. George Runton and afterwards Mr. Charles Goss, both well known African hunters, as guides and interpreters. Headquarters were made at Dodoma, 250 miles inland where Mr. Loveridge maintained the base camp. Mr. Carnochan went farther west to Tabora, Mr. Haweis, to Mhonde, and Doctor Mann spent a great deal of time on "safari" visiting the region about Lake Manyara and afterwards farther south, the Tula district. At the end of four months, the party embarked with the collection and returned to the States, via Colombo, arriving at the port of Boston October 24, having suffered comparatively small loss among the animals en route.

Among the animals secured, numbers were new to the collection. Among these, giraffe, white-bearded gnu, impalla, reed buck, and long-eared fox had never before been exhibited in the park. A male greater kudu, a female eland (the latter obtained through the efforts of the game warden, Mr. C. F. M. Swynnerton), a quartet of wart hogs, five leopards, five hyenas, ratel, and civet cats fill long-felt gaps in the collection. Among the 70 monkeys brought home were a group of five blue monkeys, a very rare and desirable species, and five purple-faced monkeys, both of these new to the history of our Zoo. From the Sudan Government was secured a splendid specimen of a shoebill stork, the second to arrive in America and the first in Washington.

There was a good series of smaller mammals, such as porcupines, hedgehogs, genets, five species of mongoose, jackals, etc.

Quantities of birds were brought home, among these a troop of six crowned cranes and two rare species of lovebirds, *Agapornis personata* and *Agapornis fischeri*, one of them unique in American collections.

Because of the lack of facilities at the park for housing them, no especial attempt was made to get reptiles in quantities, but a dozen African rock pythons, very rare in American collections, black spitting cobras, Egyptian cobras, and boomslangs were secured,

as well as the curious soft-shelled tortoises and also a cage of 50 chameleons, which made a most attractive exhibit.

During the course of the expedition a series of radio talks were given at station WRC through arrangement by A. H. Clark so that the public was kept informed on the progress of the party.

The expedition is indebted to the Governor of Tanganyika for his generous license to collect, to Messrs. C. F. M. Swynnerton, chief of the Tanganyika game department, to George Runton and Charles Goss, and to the Ellerman Steamship Line, to the officers and men of the steamships *Crewe Hall* and *City of Calcutta* for the great consideration they showed the party and its cargo of animals on its voyage home, and to Mr. John T. Benson, of Nashua, N. H., United States agent for Hagenbeck Bros., whose help at Boston greatly facilitated the landing of the collection.

Since returning from Africa, the director has given a series of about 50 lectures on the expedition, illustrated by moving pictures, which were kindly furnished by the Pathé Review.

GIFTS

Mr. H. H. Adams, Washington, D. C., ocelot.
Miss Corinne Allison, Washington, D. C., red fox.
American Consul, Trinidad, West Indies, peccary.
Mr. Robert Anderson, Washington, D. C., Cuban parrot.
Miss Bessie K. Arnold, Culpeper, Va., alligator.
Mr. Vernon Bailey, Washington, D. C., two desert turtles.
Mr. Herbert Barber, Washington, D. C., least bittern.
Dr. Thomas Barbour, Cambridge, Mass., two spotted turtles.
Mr. H. G. Bartsch, Washington, D. C., two European hedgehogs.
Mrs. L. B. Batkins, Richmond, Va., two orange-winged parrots.
Mr. Dick Binckel, Washington, D. C., four horned toads.
Mr. J. K. Bishop, Washington, D. C., double yellow-head parrot.
Commander G. E. Brandt, United States Navy, two comb lizards.
Lieut. W. K. Burgess, United States Army, Manila, P. I., 2 jungle fowls, 5 bleeding heart doves, 2 green-winged doves, 2 Java sparrows, 2 black-headed nun, 2 hanging paroquets.
California Academy of Sciences, three leopard seals.
Mr. R. S. Cardon, Washington, D. C., raccoon.
Mr. F. G. Carnochan, New York City, two wood turtles.
Mr. J. C. Carter, Washington, D. C., three canaries.
Mr. F. M. Clark, Washington, D. C., red fox.
Mrs. E. Cocksell, Washington, D. C., double-yellow-head parrot.
President Coolidge, White House, two lions, pigmy hippopotamus.
Mrs. Calvin Coolidge, White House, four paroquets, one duiker.
Mr. E. L. Crandall, Washington, D. C., margay.
Mr. W. G. Cunningham, Washington, D. C., gray fox.
Mr. H. A. Daniel, Orange, Va., red-tailed hawk.
Mr. J. J. Daniels, Washington, D. C., two alligators.
Mr. A. H. Davin, Palmyra, Va., red fox.

Mr. H. F. Davison, Washington, D. C., Cuban parrot.
Mr. J. Delacour, Cléres, France, Edward's pheasant.
Mr. Milton Derrick, Takoma Park, Md., barred owl.
Mrs. N. Eckhardt, Washington, D. C., ring-neck pheasant.
Mr. F. G. Ellison, Brentwood, Md., two turkey vultures.
Mr. Victor Evans, Washington, D. C., great anteater.
Mr. H. E. Ewing, Washington, D. C., copperhead snake.
U. S. Experiment Farm, Beltsville, Md., great horned owl.
Mr. C. L. Fagan, Rahway, N. J., white-crowned pigeon.
Mrs. J. Farley, Washington, D. C., two grass paroquets.
Mr. C. C. Fisher, Middleburg, Va., banded rattlesnake.
Mr. Edward Foutz, Washington, D. C., skunk.
Mr. F. M. Gaige, Ann Arbor, Mich., Blanding's terrapin.
Dr. Gavlin, Washington, D. C., pied-billed grebe.
Mr. F. P. Glover, Brentwood, Md., raccoon.
Mr. Granados, Washington, D. C., rough fox.
Mrs. Nancy Hall, Washington, D. C., alligator.
Mr. Oddie Hallson, Bethel, Alaska, three emperor geese.
Mr. R. L. Harrison, Garrett Park, Md., two yellow-fronted parrots.
Mrs. Henderson, Washington, D. C., orange-cheeked waxbill, black-faced finch.
Mrs. J. H. Himes, Washington, D. C., roseate cockatoo.
Mr. Albert Hochbaum, Washington, D. C., barred owl.
Mr. Carl H. Hubbs, University of Michigan, two leather-back terrapins, two Blandings terrapins, geographic terrapin.
Mr. J. A. Hyslop, Silver Spring, Md., great horned owl, two pilot snakes.
Messrs. J. A. & C. D. Hyslop & Stanny Rapley, Silver Spring, Md., two copperhead snakes.
Mr. James Jones, Washington, D. C., screech owl.
Mr. M. W. Knarr, Washington, D. C., marmoset.
Mr. Samuel Kress, Port Limon, Costa Rica, five three-toed sloths.
Lansburgh Sea Food Co., Washington, D. C., alligator.
Mr. Harrison Lee, Bastian, Va., banded rattlesnake.
Mrs. Miles A. Lehhig, McLean, Va., two mocking birds.
Mr. E. Lesche, Washington, D. C., Philippine macaque.
Mr. John C. Letts, Washington, D. C., snowy owl.
Mr. F. T. Lillie, Washington, D. C., barred owl.
Mr. C. Lindheimer, Washington, D. C., two gray-breasted paroquets.
Miss Pauline Marshall, Cocoa, Fla., barn owl.
Mr. E. C. Mateer, Park Lane, Va., alligator.
Mr. Stephen T. Mather, National Park Service, two cinnamon bears.
Mr. D. W. May, Mayaguez, P. R., horned iguana, Porto Rico boa.
Mr. J. R. McClintock, Washington, D. C., bald eagle.
Mrs. Royal Mead, Washington, D. C., two canaries.
Mr. George Mezitis, Washington, D. C., red-legged partridge.
Misses Alys and Helena Missirian, New Haven, Conn., sooty mangabey.
Mr. W. Lee Morris, Clarendon, Va., alligator.
Mr. E. E. Pabst, Washington, D. C., osprey.
Mr. E. R. Paiste, Berwyn, Pa., Canada porcupine.
Mrs. Pass, Washington, D. C., Tovi paroquet.
Mr. E. M. Perkins, Washington, D. C., banded rattlesnake.
Mr. Walter Peteet, Washington, D. C., marmoset.

Philadelphia Zoological Garden, Philadelphia, Pa., two Muhlenberg's turtles.
W. Plesses Jungle Show, pine snake.
Mr. E. D. Reid, Washington, D. C., blacksnake.
Mr. Lowry Riggs, Rockville, Md., California boa.
Mr. E. H. Sartain, Washington, D. C., woodchuck.
Mrs. C. M. Saxelby, Washington, D. C., fire finch.
Mr. W. Schaub, Fairfax, Va., great horned owl.
Mr. E. S. Schmid, Washington, D. C., two woodchucks.
Mr. H. Schriver, Cumberland, Md., five golden pheasants.
Mr. Ernest T. Seton, Greenwich, Conn., 3 skunks, 1 opossum, 14 mallards.
Mr. R. A. Shinn, Washington, D. C., diamond rattlesnake.
Mr. T. W. Sine, Maurertown, Va., alligator.
Mrs. Geo. B. Smith, Washington, D. C., red-shouldered hawk.
Mrs. C. F. Spradling, Athens, Tenn., king snake.
Mr. H. G. Stevens, Culpeper, Va., rhesus monkey.
Mrs. C. A. Strange, Enterprise, Miss., barred owl.
Mr. Swope, Chevy Chase, Md., pied-billed grebe.
Miss Vivian Torovsky, Washington, D. C., yellow-naped parrot.
Mr. J. G. Updike, Rosslyn, Va., great horned owl.
United States Biological Survey, through G. E. Holman, one wolf.
Mr. H. E. Waldron, Washington, D. C., Florida gallinule.
Mrs. Robert M. Ward, Winchester, Va., great horned owl.
Mrs. O. D. Wayland, Washington, D. C., two canaries.
Unknown donors, great blue heron, woodchuck, osprey, turkey vulture.

In addition to animals presented to the park, the office of the Chief Coordinator has secured a considerable number of useful and valuable supplies and equipment for which the park authorities are deeply grateful.

Births.—During the year 104 mammals, birds, and reptiles were born and hatched in the park and added to the collection. Among the mammals born were fallow deer, Barasingha deer, European deer, sika deer, hog deer, American bison, tahr goat, Indian antelope, guanaco, agouti, paca, Rocky Mountain sheep, European brown bear, and rhesus monkey.

The Rocky Mountain sheep are especially interesting. The flock in the park at the close of the year numbered eight individuals, of which six were born in Washington and two of them from parents also born and raised in the park.

Exchanges.—The most important among the animals received in exchange were the Mongolian wild horse, mountain zebra, and six Humboldt penguins.

Purchases.—An anoa, a pair of Chapman zebras, an Indian caracal, a yaguarundi cat, a young snow leopard, a pair of barbary sheep, a pair of wallaroos, and a South American condor are the principal purchases of the year. We were especially fortunate in securing the snow leopard to fill the place of the one that had died the preceding year, which was the only specimen of this handsome and remarkable cat in captivity in the United States.

Removals.—One hundred and twenty-eight mammals, birds, and reptiles were sent away to other zoological gardens during the year. Among these were a pair of Philippine buffalo, various deer, some small mammals and birds and reptiles from the Smithsonian-Chrysler expedition.

Losses by death were mainly of animals that had been long in the collection or very recently received. Among the former was a Manchurian tiger, which lived in the park from June, 1918, to March 12, 1927; a cheetah received August 8, 1913, died February 17, 1927; a mountain sheep that had lived from September 18, 1917, to May 3, 1927; an eland received June 9, 1916, died August 22, 1926; a wild boar received September 10, 1911, died December 9, 1926; a northern wild cat received January 15, 1912, died January 28, 1927; a large male sea lion received August 29, 1916, and died June 13, 1927. Several of these have established long records for longevity in captivity but nevertheless leave great gaps in the collection.

One of a pair of Chapman zebras died through an accident, injuring himself by leaping into the fence. The Humboldt penguin died of aspergillosis.

The loss in the reptile collection has been larger than in other groups owing to lack of suitable quarters.

Post-mortem examinations were made in most cases by the pathological division of the Bureau of Animal Industry. The following list shows the results of autopsies, the cases being arranged by groups:

CAUSES OF DEATH

MAMMALS

Marsupialia: Pneumonia, 2; congestion of lungs, 1; enteritis, 1; infection of jaw, 1; no cause found, 1.

Carnivora: Tuberculosis, 2; congestion of lungs, 1; gastroenteritis, 3; intestinal parasites, 1; intestinal obstruction, 3; tumor, 1; softening of brain, 1.

Pinnipedia: Congestion of lungs, 1; gastroenteritis, 2.

Primates: Pneumonia, 1; enteritis, 2; gastroenteritis, 2; intestinal parasites, 1; nephritis, 1; streptococcic infection, 1; malnutrition, 1; no cause found, 2.

Artiodactyla: Pneumonia, 1; tuberculosis, 1; congestion of lungs, 1; gastroenteritis, 3; hepatitis, 1; nephritis, 1; necrophorus infection, 2; tumor, 1; accident, 2; old age, 3.

BIRDS

Struthioniformes: Aspergillosis, 1; peritonitis, 1.

Rheiformes: Egg-bound, 1; no cause found, 1.

Sphenisciformes: Pneumonia, 1; aspergillosis, 5.

Galliformes: Aspergillosis, 1; hepatitis, 1.

Psittaciformes: Enteritis, 2; no cause found, 1.

Passeriformes: Aspergillosis, 1; no cause found, 1.

The animals lost by death which were of value for museum purposes were transferred to the United States National Museum for preserva-

tion. In all, 244 specimens were sent. This does not include a number of Tanganyika specimens which died immediately upon arrival in Washington. A number of rare birds' eggs were also sent to the Museum.

A few mammals especially desired at the Johns Hopkins Medical School were sent, after death, to that institution.

ANIMALS IN THE COLLECTION JUNE 30, 1927

MAMMALS

MARSUPIALIA

Virginia opossum (*Didelphis virginiana*)	2
Tasmanian devil (*Sarcophilus harrisii*)	1
Flying phalanger (*Petaurus breviceps*)	5
Brush-tailed rock wallaby (*Petrogale penicillata*)	1
Wallaroo (*Macropus robustus*)	2
Wombat (*Phascolomys mitchelli*)	1

CARNIVORA

Kadiak bear (*Ursus middendorffi*)	2
Alaska Peninsula bear (*Ursus gyas*)	4
Yakutat bear (*Ursus dalli*)	1
Kidder's bear (*Ursus kidderi*)	2
European bear (*Ursus arctos*)	8
Grizzly bear (*Ursus horribilis*)	1
Apache grizzly (*Ursus apache*)	1
Himalayan bear (*Ursus thibetanus*)	1
Black bear (*Euarctos americanus*)	4
Cinnamon bear (*Euarctos americanus cinnamomum*)	4
Glacier bear (*Euarctos emmonsii*)	1
Sun bear (*Helarctos malayanus*)	1
Polar bear (*Thalarctos maritimus*)	2
Dingo (*Canis dingo*)	2
Gray wolf (*Canis nubilus*)	6
Florida wolf (*Canis floridanus*)	1
Texas red wolf (*Canis rufus*)	1
Coyote (*Canis latrans*)	5
Hybrid coyote (*Canis latrans-rufus*)	4
California coyote (*Canis ochropus*)	1
Black-backed jackal (*Canis mesomelas*)	1
Rough fox (*Cerdocyon cancrivorus*)	2
Red fox (*Vulpes fulva*)	6
Silver-black fox (*Vulpes fulva*)	1
European fox (*Vulpes vulpes*)	1
Kit fox (*Vulpes velox*)	2
Gray fox (*Urocyon cinereoargenteus*)	1
Bush dog (*Icticyon venaticus*)	1
Cacomistle (*Bassariscus astutus*)	1
Raccoon (*Procyon lotor*)	10
Florida raccoon (*Procyon lotor elucus*)	1
Gray coatimundi (*Nasua narica*)	2
Kinkajou (*Potos flavus*)	1
Mexican kinkajou (*Potos flavus aztecus*)	1
Fisher (*Martes pennanti*)	1
Skunk (*Mephitis nigra*)	4
American badger (*Taxidea taxus*)	2
Ratel (*Mellivora capensis*)	1
Florida otter (*Lutra canadensis vaga*)	3
Indian civet (*Viverra zibetha*)	1
East African civet (*Viverra civetta orientalis*)	1
Palm civet (*Paradoxurus hermaphroditus*)	2
Egyptian mongoose (*Herpestes ichneumon*)	1
Banded mongoose (*Herpestes mungo colonus*)	1
Neumann's genet (*Genetta dongalana neumanni*)	4
East African genet (*Genetta suahelica*)	1
Aard-wolf (*Proteles cristatus*)	1
Spotted hyena (*Crocuta crocuta*)	1
East African spotted hyena (*Crocuta crocuta germinans*)	5
Striped hyena (*Hyæna hyæna*)	1
African cheetah (*Acinonyx jubatus*)	1
Lion (*Felis leo*)	5
Bengal tiger (*Felis tigris*)	1
Manchurian tiger (*Felis tigris longipilis*)	4
Leopard (*Felis pardus*)	1
Black leopard (*Felis pardus*)	1
East African leopard (*Felis pardus suahelicus*)	4
Jaguar (*Felis onca*)	1
Serval (*Felis serval*)	1
East African serval (*Felis capensis hindei*)	1
Ocelot (*Felis pardalis*)	2
Brazilian ocelot (*Felis pardalis brasiliensis*)	1
Snow leopard (*Felis uncia*)	1
Mexican puma (*Felis azteca*)	3
Mountain lion (*Felis hippolestes*)	1
Yaguarundi (*Felis yagouaroundi*)	1
Indian caracal (*Lynx caracal*)	1
Canada lynx (*Lynx canadensis*)	1
Bay lynx (*Lynx rufus*)	3
Clouded leopard (*Neofelis nebulosa*)	1

PINNIPEDIA

Leopard seal (*Phoca richardii var.*)	3
San Geronimo harbor seal (*Phoca richardii geronimensis*)	1

RODENTIA

Woodchuck (*Marmota monax*)	8
Prairie dog (*Cynomys ludovicianus*)	9
Honduras squirrel (*Sciurus boothiæ*)	1
Albino squirrel (*Sciurus carolinensis*)	2
Flying squirrel (*Sciuropterus volucella*)	3
American beaver (*Castor canadensis*)	4
African porcupine (*Hystrix africæ-australis*)	1
East African porcupine (*Hystrix galeata*)	7
Malay porcupine (*Acanthion brachyurum*)	2
East African gray mouse (*Graphiurus sp.*)	1
East African tree mouse (*Lemiscomys sp.*)	1
Viscacha (*Lagostomus trichodactylus*)	1
Central American paca (*Cuniculus paca virgatus*)	5
Sooty agouti (*Dasyprocta fuliginosa*)	1
Speckled agouti (*Dasyprocta punctata*)	2
Azara's agouti (*Dasyprocta azaræ*)	1
Trinidad agouti (*Dasyprocta rubrata*)	4
Guinea pig (*Cavia porcellus*)	10
Capybara (*Hydrochærus hydrochæris*)	1

LAGOMORPHA

Domestic rabbit (*Oryctolagus cuniculus*)	10

PRIMATES

Zanzibar lemur (*Galago garnetti*)	1
Senaar lemur (*Galago senaariensis*)	1
Pangani lemur (*Galago pangani*)	1
Ring-tailed lemur (*Lemur catta*)	1
Red-fronted lemur (*Lemur rufifrons*)	1
Black lemur (*Lemur macaco*)	2
Gray spider monkey (*Ateles geoffroyi*)	2
Humboldt's woolly monkey (*Lagothrix humboldti*)	1
White-throated capuchin (*Cebus capucinus*)	1
Brown capuchin (*Cebus fatuellus*)	2
Margarita capuchin (*Cebus margaritæ*)	1
Gelada baboon (*Theropithecus obscurus*)	1
Chacma (*Papio porcarius*)	1
Anubis baboon (*Papio cynocephalus*)	10
Olive baboon (*Papio neumanni*)	8
East African baboon (*Papio ibeanus*)	1
Mandrill (*Papio sphinx*)	3
Drill (*Papio leucophæus*)	1
Moor macaque (*Cynopithecus maurus*)	4
Barbary ape (*Simia sylvanus*)	2
Japanese macaque (*Macaca fuscata*)	3
Pig-tailed monkey (*Macaca nemestrina*)	1
Burmese macaque (*Macaca andamanensis*)	1
Rhesus monkey (*Macaca rhesus*)	11
Crab-eating macaque (*Macaca irus*)	1
Philippine macaque (*Macaca syrichta*)	2
Javan macaque (*Macaca mordax*)	6
Sooty mangabey (*Cercocebus fuliginosus*)	4
Hagenbeck's mangabey (*Cercocebus hagenbecki*)	1
White-collared mangabey (*Cercocebus torquatus*)	1
Green guenon (*Lasiopyga callitrichus*)	2
Johnston's vervet (*Lasiopyga pygerythra johnstoni*)	15
Sykes' guenon (*Lasiopyga albigularis*)	5
Mona guenon (*Lasiopyga mona*)	2
De Brazza's guenon (*Lasiopyga brazzæ*)	1
Lesser white-nosed guenon (*Lasiopyga petaurista*)	1
Hanuman monkey (*Semnopithecus entellus*)	1
Gray gibbon (*Hylobates leuciscus*)	1
Chimpanzee (*Pan satyrus*)	2
Orang-utan (*Pongo pygmæus*)	1

ARTIODACTYLA

Wart hog (*Phacochærus æthiopicus*)	3
River hog (*Potamochærus africanus*)	2
Collared peccary (*Pecari angulatus*)	2
Hippopotamus (*Hippopotamus amphibius*)	2
Pigmy hippopotamus (*Chæropsis liberiensis*)	1
Bactrian camel (*Camelus bactrianus*)	1
Arabian camel (*Camelus dromedarius*)	1
Guanaco (*Lama huanachus*)	3
Llama (*Lama glama*)	5
Reindeer (*Rangifer tarandus*)	12
Fallow deer (*Dama dama*)	8
White fallow deer (*Dama dama*)	2
Axis deer (*Axis axis*)	4
Hog deer (*Hyelaphus porcinus*)	4
Sambar (*Rusa unicolor*)	1
Barasingha (*Rucervus duvaucelii*)	5
Burmese deer (*Rucervus eldii*)	1
Japanese deer (*Sika nippon*)	13
Red deer (*Cervus elaphus*)	12
Kashmir deer (*Cervus hanglu*)	2
Bedford deer (*Cervus xanthopygus*)	5
American elk (*Cervus canadensis*)	5
Guatemala deer (*Odocoileus sp.*)	1
Mule deer (*Odocoileus hemionus*)	3
Blesbok (*Damaliscus albifrons*)	1
White-tailed gnu (*Connochætes gnu*)	1
Brindled gnu (*Connochætes taurinus*)	1
White-bearded gnu (*Connochætes taurinus albojubatus*)	2
Lechwe (*Onotragus leche*)	1
Sable antelope (*Egocerus niger*)	1
Reed buck (*Redunca bohor*)	1
East African impalla (*Æpyceros melampus suara*)	2
Indian antelope (*Antilope cervicapra*)	3
Nilgai (*Boselaphus tragocamelus*)	2
East African eland (*Taurotragus oryx livingstonii*)	1
Mountain goat (*Oreamnos americanus*)	3
Tahr (*Hemitragus jemlahicus*)	9
Alpine ibex (*Capar ibex*)	3

Aoudad (*Ammotragus lervia*)	3
Rocky Mountain sheep (*Ovis canadensis*)	8
Mouflon (*Ovis europæus*)	7
Greenland musk-ox (*Ovibos moschatus wardi*)	2
Zebu (*Bos indicus*)	1
Yak (*Poëphagus grunniens*)	6
American bison (*Bison bison*)	17
Anoa (*Anoa depressicornis*)	1
Indian buffalo (*Bubalus bubalis*)	2

PERISSODACTYLA

Malay tapir (*Tapirus indicus*)	1
Brazilian tapir (*Tapirus terrestris*)	1
Baird's tapir (*Tapirella bairdii*)	1
Mongolian horse (*Equus przewalskii*)	1
Mountain zebra (*Equus zebra*)	1
Chapman's zebra (*Equus quagga chapmani*)	2
Zebra-horse hybrid (*Equus grevyi-caballus*)	1
Zebra-ass hybrid (*Equus grevyi-asinus*)	1

PROBOSCIDEA

Abyssinian elephant (*Loxodonta africana oxyotis*)	1
Sumatran elephant (*Elephas sumatranus*)	1

BIRDS

STRUTHIONIFORMES

South African ostrich (*Struthio australis*)	3
Somaliland ostrich (*Struthio molybdophanes*)	1
Nubian ostrich (*Struthio camelus*)	1

RHEIFORMES

Rhea (*Rhea americana*)	2

CASUARIIFORMES

Australian cassowary (*Casuarius australis*)	1
Single-wattled cassowary (*Casuarius uniappendiculatus*)	1
Sclater's cassowary (*Casuarius philipi*)	1
Emu (*Dromiceius novæhollandiæ*)	2

SPHENISCIFORMES

Rock-hopper penguin (*Catarrhactes pachyrhynchus*)	1

CICONIIFORMES

American white pelican (*Pelecanus erythrorhynchos*)	8
European white pelican (*Pelecanus onocrotalus*)	2
Roseate pelican (*Pelecanus roseus*)	2
Australia pelican (*Pelecanus conspicillatus*)	2
Brown pelican (*Pelecanus occidentalis*)	7
California brown pelican (*Pelecanus californicus*)	5
Florida cormorant (*Phalacrocorax auritus floridanus*)	2
Brandt's cormorant (*Phalacrocorax penicillatus*)	1
Great white heron (*Ardea occidentalis*)	1
Great blue heron (*Ardea herodias*)	1
Goliath heron (*Ardea goliath*)	1
East African heron (*Ardea melanocephela*)	1
American egret (*Casmerodius egretta*)	1
Black-crowned night heron (*Nycticorax nycticorax nævius*)	77
Boatbill (*Cochlearius cochlearius*)	2
White stork (*Ciconia ciconia*)	1
Black stork (*Ciconia nigra*)	1
Marabou stork (*Leptoptilus crumeniferus*)	2
Shoe-bill (*Balæniceps rex*)	1
Wood ibis (*Mycteria americana*)	2
Sacred ibis (*Threskiornis æthiopicus*)	3
Black-headed ibis (*Threskiornis melanocephalus*)	3
Australian ibis (*Threskiornis strictipennis*)	2
White ibis (*Guara alba*)	8
Scarlet ibis (*Guara rubra*)	3

ANSERIFORMES

Mallard (*Anas platyrhynchos*)	48
Black duck (*Anas rubripes*)	7
Australian black duck (*Anas superciliosa*)	1
African pintail (*Anas erythrorhyncha*)	2
Gadwall (*Chaulelasmus streperus*)	13
European widgeon (*Mareca penelope*)	3
Baldpate (*Mareca americana*)	7
Green-winged teal (*Nettion carolinense*)	3
European teal (*Nettion crecca*)	4
Baikal teal (*Nettion formosum*)	5
Blue-winged teal (*Querquedula discors*)	1
Garganey (*Querquedula querquedula*)	6
Shoveller (*Spatula clypeata*)	1
Pintail (*Dafila acuta*)	11
Bahaman pintail (*Dafila bahamensis*)	1
Wood duck (*Aix sponsa*)	8
Mandarin duck (*Dendronessa galericulata*)	9
Canvasback (*Marila valisineria*)	7
European pochard (*Marila ferina*)	3
Redhead (*Marila americana*)	11
Ring-necked duck (*Marila collaris*)	2
Tufted duck (*Marila fuligula*)	1
Lesser scaup duck (*Marila affinis*)	1
Greater scaup duck (*Marila marila*)	3
Rosy-billed pochard (*Metopiana peposaca*)	4

Hawaiian goose (*Nesochen sandvicensis*)	2
Snow goose (*Chen hyperboreus*)	1
Greater snow goose (*Chen hyperboreus nivalis*)	1
Blue goose (*Chen cœrulescens*)	5
White-fronted goose (*Anser albifrons*)	4
American white-fronted goose (*Anser albifrons gambeli*)	1
Bean goose (*Anser fabalis*)	2
Pink-footed goose (*Anser brachyrhynchus*)	2
Chinese goose (*Cygnopsis cygnoides*)	3
Bar-headed goose (*Eulabeia indica*)	2
Canada goose (*Branta canadensis*)	9
Hutchins's goose (*Branta canadensis hutchinsii*)	3
White-cheeked goose (*Branta canadensis occidentalis*)	16
Cackling goose (*Branta canadensis minima*)	2
Brant (*Branta bernicla glaucogastra*)	12
Barnacle goose (*Branta leucopsis*)	4
Emperor goose (*Philacte canagica*)	3
Muscovy duck (*Cairina moschata*)	3
Pied goose (*Anseranas semipalmata*)	1
Black-bellied tree duck (*Dendrocygna autumnalis*)	2
Eyton's tree duck (*Dendrocygna eytoni*)	4
Mute swan (*Cygnus gibbus*)	3
Whistling swan (*Cygnus columbianus*)	1
Black swan (*Chenopis atrata*)	4

FALCONIFORMES

Condor (*Vultur gryphus*)	1
California condor (*Gymnogyps californianus*)	3
Turkey vulture (*Cathartes aura*)	5
Black vulture (*Coragyps urubu*)	1
King vulture (*Sarcoramphus papa*)	2
Secretary bird (*Sagittarius serpentarius*)	1
Griffon vulture (*Gyps fulvus*)	1
African black vulture (*Torgos tracheliotus*)	1
Cinereous vulture (*Ægypius monachus*)	2
White-headed vulture (*Trigonoceps occipitalis*)	1
Caracara (*Polyborus cheriway*)	3
Black-shouldered kite (*Elanus cœruleus*)	1
African black kite (*Milvus migrans parasiticus*)	1
Wedge-tailed eagle (*Uroaëtus audax*)	2
Golden eagle (*Aquila chrysaëtos*)	5
Tawny eagle (*Aquila rapax*)	2
White-bellied sea eagle (*Cuncuma leucogaster*)	2
Bald eagle (*Haliæetus leucocephalus leucocephalus*)	9
Alaskan bald eagle (*Haliæetus leucocephalus alascanus*)	3
Red-tailed hawk (*Buteo borealis*)	9
East African chanting goshawk (*Melierax poliopterus*)	1
Pigmy falcon (*Poliohierax semitorquatus*)	1
Sparrow hawk (*Falco sparverius*)	3
South African lanner (*Falco biarmicus*)	1

GALLIFORMES

Panama curassow (*Crax panamensis*)	2
Razor-billed curassow (*Mitu mitu*)	4
Crested guan (*Penelope boliviana*)	1
Mexican guan (*Ortalis vetula*)	2
Vulturine guinea fowl (*Acryllium vulturinum*)	2
Grants' crested guinea fowl (*Guttera granti*)	1
Reichenow's helmeted guinea fowl (*Numida mitrata reichenowi*)	12
Peafowl (*Pavo cristatus*)	10
Albino peafowl (*Pavo cristatus*)	4
Silver pheasant (*Gennæus nycthemerus*)	1
Edwards' pheasant (*Gennæus edwardsi*)	1
Golden pheasant (*Chrysolophus pictus*)	5
Lady Amherst's pheasant (*Chrysolophus amherstiæ*)	1
Ring-necked pheasant (*Phasianus torquatus*)	13
Red-legged partridge (*Alectoris græca*)	1
Migratory quail (*Coturnix coturnix*)	10
Valley quail (*Lophortyx californica vallicola*)	1
Scaled quail (*Callipepla squamata*)	5

GRUIFORMES

Florida gallinule (*Gallinula galeata*)	2
African moorhen (*Gallinula chloropus brachyptera*)	4
East Indian gallinule (*Porphyrio calvus*)	1
Pukeko (*Porphyrio stanleyi*)	1
Black-tailed moor hen (*Microtribonyx ventralis*)	2
American coot (*Fulica americana*)	1
African black crake (*Limnocrax flavirostra*)	1
Lesser rail (*Hypotænidia philippensis*)	2
South Island weka rail (*Ocydromus australis*)	2
Short-winged weka (*Ocydromus brachypterus*)	2
Sandhill crane (*Megalornis mexicana*)	4
Little brown crane (*Megalornis canadensis*)	3
White-necked crane (*Megalornis leucauchen*)	1
Indian white crane (*Megalornis leucogeranus*)	1
Lilford's crane (*Megalornis lilfordi*)	1
Australian crane (*Mathewsena rubicunda*)	2
Demoiselle crane (*Anthropoides virgo*)	3
Crowned crane (*Balearica pavonina*)	1
East African crowned crane (*Balearica regulorum gibbericeps*)	5
Kagu (*Rhynochetos jubatus*)	2

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CHARADRIIFORMES

Ruff (*Philomachus pugnax*)	3
Lapwing (*Vanellus vanellus*)	1
Yellow-wattled lapwing (*Lobivanellus indicus*)	1
South American stone-plover (*Œdicnemus bistriatus vocifer*)	1
Pacific gull (*Gabianus pacificus*)	1
Great black-backed gull (*Larus marinus*)	2
Western gull (*Larus occidentalis*)	6
Herring gull (*Larus argentatus*)	3
Silver gull (*Larus novæhollandiæ*)	23
Laughing gull (*Larus atricilla*)	2
Inca tern (*Noddi inca*)	1
Victoria crowned pigeon (*Goura victoria*)	1
Bronze-wing pigeon (*Phaps chalcoptera*)	2
Bleeding-heart dove (*Gallicolumba luzonica*)	9
Wood pigeon (*Columba palumbus*)	7
White-crowned pigeon (*Columba leucocephala*)	1
Triangular spotted pigeon (*Columba guinea*)	4
Mourning dove (*Zenaidura macroura*)	1
Mexican dove (*Zenaidura graysoni*)	1
White-fronted dove (*Leptotila fulviventris brachyptera*)	4
Necklaced dove (*Spilopelia tigrina*)	9
Emerald spotted dove (*Turtur chalcospilos*)	22
Ringed turtledove (*Streptopelia risoria*)	5
East African ring-necked dove (*Streptopelia capicola tropica*)	35
Masai mourning dove (*Streptopelia decipiens perspicillata*)	12
Zebra dove (*Geopelia striata*)	3
Bar-shouldered dove (*Geopelia humeralis*)	1
Cape masked dove (*Œna capensis*)	12
Inca dove (*Scardafella inca*)	1
Cuban ground dove (*Chæmepelia passerina aflavida*)	1
Green-winged dove (*Chalcophaps indica*)	2
Pacific fruit pigeon (*Globicera pacifica*)	2
Bronze fruit pigeon (*Muscadivores ænea*)	1
Malay spotted dove (*Spilopelia tigrina*)	1

PSITTACIFORMES

Kea (*Nestor notabilis*)	1
Roseate cockatoo (*Kakatoe roseicapilla*)	13
Bare-eyed cockatoo (*Kakatoe gymnopis*)	1
Leadbeater's cockatoo (*Kakatoe leadbeateri*)	3
White cockatoo (*Kakatoe alba*)	1
Sulphur-crested cockatoo (*Kakatoe galerita*)	6
Mexican green macaw (*Ara mexicana*)	2
Severe macaw (*Ara severa*)	1
Blue-and-yellow macaw (*Ara ararauna*)	7
Red-and-blue-and-yellow macaw (*Ara macao*)	4
Gray-breasted paroquet (*Myopsitta monachus*)	2
Petz's paroquet (*Eupsittula canicularis*)	5
Golden-crowned paroquet (*Eupsittula aurea*)	3
Weddell's paroquet (*Eupsittula weddellii*)	3
Blue-winged parrotlet (*Psittacula passerina*)	13
Golden paroquet (*Brotogeris chrysosema*)	1
Tovi paroquet (*Brotogeris jugularis*)	7
Yellow-naped parrot (*Amazona auropalliata*)	2
Mealy parrot (*Amazona farinosa*)	1
Orange-winged parrot (*Amazona amazonica*)	5
Blue-fronted parrot (*Amazona æstiva*)	1
Red-crowned parrot (*Amazona viridigenalis*)	3
Double-yellow-head parrot (*Amazona oratrix*)	11
Yellow-headed parrot (*Amazona ochrocephala*)	7
Festive parrot (*Amazona festiva*)	3
Lesser white-fronted parrot (*Amazona albifrons nana*)	1
Santo Domingo parrot (*Amazona ventralis*)	3
Cuban parrot (*Amazona leucocephala*)	4
Maximilian's parrot (*Pionus maximiliani*)	1
Dusky parrot (*Pionus fuscus*)	1
Blue-headed parrot (*Pionus menstruus*)	1
Amazonian caique (*Pionites xanthomeria*)	5
Black-headed caique (*Pionites melanocephala*)	2
East African brown parrot (*Poicephalus meyeri matschiei*)	2
Lesser vasa parrot (*Coracopsis nigra*)	1
Greater vasa parrot (*Coracopsis vasa*)	1
Red-faced love bird (*Agapornis pullaria*)	7
Gray-headed love bird (*Agapornis madagascariensis*)	8
Yellow-collared love bird (*Agapornis personata*)	5
Fischer's love bird (*Agapornis fischeri*)	5
Blue-bonnet paroquet (*Psephotus hæmatorrhous*)	1
Pennant's paroquet (*Platycercus elegans*)	1
Black-tailed paroquet (*Polytelis melanura*)	1
Red-shining paroquet (*Pyrrhulopsis splendens*)	1
King paroquet (*Aprosmictus cyanopygius*)	1
Crimson-winged paroquet (*Aprosmictus erythropterus*)	1

Ring-necked paroquet (*Conurus torquatus*)	1
Nepalese paroquet (*Conurus nepalensis*)	2
Grass paroquet (*Melopsittacus undulatus*)	19

CORACIIFORMES

Jackson's hornbill (*Lophoceros jacksoni*)	2
Groove-billed toucanet (*Aulacorhamphus sulcatus*)	1
Emin Pasha's barbet (*Trachyphonus emini*)	1
Morepork owl (*Spiloglaux novæseelandiæ*)	1
Barred owl (*Strix varia*)	11
Florida barred owl (*Strix varia alleni*)	1
Snowy owl (*Nyctea nyctea*)	3
Screech owl (*Otus asio*)	3
East African white-eared owl (*Otus leucotis granti*)	2
Great horned owl (*Bubo virginianus*)	13
Eagle owl (*Bubo bubo*)	1
Spotted eagle owl (*Bubo africanus*)	1
American barn owl (*Tyto alba pratincola*)	7
African barn owl (*Tyto alba affinis*)	8
Red-shafted flicker (*Colaptes cafer collaris*)	3

PASSERIFORMES

Cock of the rock (*Rupicola rupicola*)	1
Naked-throated bell-bird (*Chasmorhynchus nudicollis*)	1
Mockingbird (*Mimus polyglottos*)	1
Silver-eared hill-tit (*Mesia argentauris*)	2
Red-billed hill-tit (*Liothrix luteus*)	19
Black-gorgeted laughing thrush (*Garrulax pectoralis*)	2
White-eared bulbul (*Otocompsa leucotis*)	3
Red-eared bulbul (*Otocompsa jocosa*)	2
Black-headed bulbul (*Molpastes hæmorrhous*)	3
Piping crow-shrike (*Gymnorhina tibicen*)	2
White-necked raven (*Corvultur albicollis*)	1
European raven (*Corvus corax*)	1
American raven (*Corvus corax sinuatus*)	5
Australian crow (*Corvus coronoides*)	1
American crow (*Corvus brachyrhynchos*)	1
White-breasted crow (*Corvus albus*)	5
American magpie (*Pica pica hudsonia*)	3
Yucatan jay (*Cissilopha yucatanica*)	1
Blue jay (*Cyanocitta cristata*)	2
Green jay (*Xanthoura luxuosa*)	3
Blue honey-creeper (*Cyanerpes cyaneus*)	1
Blue-winged tanager (*Tanagra cyanoptera*)	1
Blue tanager (*Thraupis cana*)	1
Giant whydah (*Diatropura progne*)	1
Paradise whydah (*Steganura paradisea*)	2
Shaft-tailed whydah (*Tetrænura regia*)	1
Red-crowned bishop bird (*Pyromelana sylvatica*)	12
Red-billed weaver (*Quelea quelea*)	1
Buffalo weaver (*Textor albirostris*)	2
Black-winged coral-billed weaver (*Textor niger nyassæ*)	25
Madagascar weaver (*Foudia madagascariensis*)	6
Black-headed weaver (*Hyphanturgus nigriceps*)	30
Emin's scaly-headed finch (*Sporopipes frontalis emini*)	25
St. Helena waxbill (*Estrilda astrilda*)	4
Orange-cheeked waxbill (*Estrilda melpoda*)	1
Rosy-rumped waxbill (*Estrilda rhodopygia*)	1
Blue-headed blue waxbill (*Uræginthus bengalus cyanocephalus*)	5
East African fire-throated finch (*Pytilia kirki*)	10
Nutmeg finch (*Munia punctulata*)	103
White-headed nun (*Munia maja*)	1
Black-headed nun (*Munia atricapilla*)	16
Chestnut-breasted finch (*Munia castaneithorax*)	2
Java finch (*Munia oryzivora*)	27
Masked grassfinch (*Poëphila personata*)	5
Diamond finch (*Steganopleura guttata*)	5
Zebra finch (*Tæniopygia castanotis*)	15
Cutthroat finch (*Amadina fasciata*)	14
Tanganyika cutthroat finch (*Amadina fasciata alexanderi*)	12
Red-headed finch (*Amadina erythrocephala*)	2
Yellow-headed marshbird (*Agelaius icterocephalus*)	2
Australian gray jumper (*Struthidea cinerea*)	1
Starling (*Sturnus vulgaris*)	9
Shining starling (*Lamprocorax metallicus*)	3
Southern glossy starling (*Lamprocolius pestis*)	8
Crested mynah (*Æthiopsar cristatellus*)	1
Malay grackle (*Gracula javana*)	1
Bare-jawed troupial (*Gymnomystax melanicterus*)	1
Hooded oriole (*Icterus cucullatus*)	1
Yellow-tailed oriole (*Icterus mesomelas*)	1
Purple grackle (*Quiscalus quiscula*)	1
Greenfinch (*Chloris chloris*)	3
European goldfinch (*Carduelis carduelis*)	4
Brambling (*Fringilla montifringilla*)	4
Yellowhammer (*Emberiza citrinella*)	1
House finch (*Carpodacus mexicanus frontalis*)	2

San Lucas house finch (*Carpodacus mexicanus ruberrimus*)	2
Canary (*Serinus canarius*)	12
Little yellow serin (*Serinus icterus*)	15
Gray singing finch (*Serinus leucopygius*)	9
White-throated sparrow (*Zonotrichia albicollis*)	1
San Diego song sparrow (*Melospiza melodia cooperi*)	2
Coastal pale-bellied sparrow (*Passer griseus suahelicus*)	20
Saffron finch (*Sicalis flaveola*)	9
Blue grosbeak (*Guiraca cærulea*)	2
Red-crested cardinal (*Paroaria cucullata*)	8

REPTILES

Alligator (*Alligator mississipiensis*)	29
Horned toad (*Phrynosoma cornutum*)	5
Blainville's horned toad (*Phrynosoma blainvillii*)	4
Gila monster (*Heloderma suspectum*)	5
Beaded lizard (*Heloderma horridum*)	1
Gould's monitor (*Varanus gouldii*)	1
Egyptian monitor (*Varanus niloticus*)	1
Philippine monitor (*Varanus salvator*)	1
West Indian iguana (*Cyclura cornuta*)	1
Rock python (*Python molurus*)	1
Regal python (*Python reticulatus*)	1
African python (*Python sebæ*)	10
Anaconda (*Eunectes murinus*)	2
Boa constrictor (*Constrictor constrictor*)	3
California boa (*Lichanura roseofusca*)	1
Porto Rican tree-boa (*Epicrates angulifer*)	10
Brazilian tree-boa (*Epicrates crassus*)	1
Black snake (*Coluber constrictor*)	1
Corn snake (*Elaphe guttata*)	1
Pine snake (*Pituophis melanoleucus*)	2
King snake (*Lampropeltis getulus*)	1
Water snake (*Natrix sipedon*)	2
Haitian snake (*Ialtris dorsalis*)	1
Egyptian cobra (*Naja haie*)	3
Black-necked spitting cobra (*Naja nigricollis*)	2
Boomslang (*Dispholidus typus*)	5
Copperhead (*Agkistrodon mokasen*)	3
Fer-de-lance (*Bothrops lanceolatus*)	1
Florida rattlesnake (*Crotalus adamanteus*)	2
Western diamond rattlesnake (*Crotalus atrox*)	1
Banded rattlesnake (*Crotalus horridus*)	4
Snapping turtle (*Chelydra serpentina*)	2
Florida snapping turtle (*Chelydra osceola*)	1
Matamata (*Chelys fimbriata*)	1
African mud terrapin (*Pelusius nigricans*)	26
African snake-necked terrapin (*Pelomedusa galeata*)	40
Brazilian snake-necked terrapin (*Hydraspis hilarii*)	1
Diamond-back terrapin (*Malaclemys centrata*)	4
Geographic terrapin (*Graptemys geographica*)	1
Spotted terrapin (*Clemmys guttata*)	3
Soft-shelled terrapin (*Amyda spinifera*)	2
Musk turtle (*Sternotherus odoratus*)	1
Mexican musk turtle (*Kinosternon sonoriense*)	1
South American musk turtle (*Kinosternon scorpioides*)	5
Pennsylvania musk turtle (*Kinosternon subrubrum*)	2
Wood turtle (*Clemmys insculpta*)	2
Leprous terrapin (*Clemmys leprosa*)	1
Muhlenberg's terrapin (*Clemmys muhlenbergi*)	2
Blanding's terrapin (*Emys blandingii*)	2
European pond turtle (*Emys orbicularis*)	1
South American terrapin (*Nicoria punctularia*)	1
South African turtle (*Homopus areolatus*)	1
Reeves turtle (*Geoclemys reevesi*)	1
Loochoo turtle (*Geoemyda spengleri*)	1
Ceylon terrapin (*Geoemyda thermalis*)	10
Painted turtle (*Chrysemys picta*)	2
Western painted turtle (*Chrysemys belli*)	1
Central American cooter (*Pseudemys ornata*)	2
Gopher tortoise (*Gopherus polyphemus*)	1
Duncan Island tortoise (*Testudo ephippium*)	3
Indefatigable Island tortoise (*Testudo porteri*)	1
Albemarle Island tortoise (*Testudo vicina*)	2
South American tortoise (*Testudo denticulata*)	1
Hermann's tortoise (*Testudo hermanni*)	1
Angulated tortoise (*Testudo angulata*)	1
Bell's tortoise (*Testudo belli*)	6
Leopard tortoise (*Testudo pardalis*)	12
Agassiz's tortoise (*Testudo agassizii*)	1
Berlandier's tortoise (*Testudo berlandieri*)	1
Iberian tortoise (*Testudo iberia*)	1
Soft-shelled tortoise (*Testudo loveridgi*)	30
Chicken turtle (*Deirochelys reticularia*)	1

BATRACHIANS

African smooth-clawed frog (*Xenopus mulleri*)	30
Fire salamander (*Salamandra maculosa*)	1
Giant salamander (*Megalobatrachus japonicus*)	2
Congo snake (*Amphiuma means*)	1

Statement of the collection

	Mammals	Birds	Reptiles and batrachians	Total
Presented and collected by expedition				1,353
Born	41	33	30	104
Received in exchange	2	25	2	29
Purchased	30	14	2	46
Transferred from other Government departments	1	2		3
Total	74	74	34	1,535

SUMMARY

Animals on hand July 1, 1926	1,619
Accessions during the year	1,535
Total animals handled	3,154
Deduct loss (by death, return of animals, and exchange)	788
	2,366

Status of collection

	Species	Individuals
Mammals	195	532
Birds	321	1,515
Reptiles and batrachians	76	319
	592	2,366

Although the list of animals has been augmented considerably, there are still numerous gaps in large and important forms. Many of the larger animals now in the collection are very old and will undoubtedly have to be replaced in the near future.

VISITORS

The attendance as recorded on the daily reports of the park was very much larger than any other year in the history of the Zoo. Attendance by months was as follows:

1926		1927	
July	247,500	January	74,650
August	315,100	February	73,800
September	321,550	March	188,850
October	172,000	April	326,580
November	440,800	May	371,400
December	75,300	June	259,700
		Total for year	2,867,230

The great crowds of visitors in November were attracted by the new animals brought from Africa.

Schools, classes, and similar organizations that visited the park numbered 370. Among them was the 4-H Club of the Department of Agriculture. The total number of persons in organized classes was about 25,000.

IMPROVEMENTS

A new flight cage, 30 by 60 feet and 35 feet high, containing two small pools, was installed in the ravine below the large flight cage. This houses gulls, terns, ibises, and other water birds and gives them opportunity to nest and raise their young unmolested by the pelicans and other large birds with which they formerly were continually in conflict. The large accessions from the Smithsonian-Chrysler expedition necessitated alterations in the lion house, bird house, and monkey house to accommodate them. Practically all the cages in the monkey house were divided each into two. The bird house was remodeled to secure quarters for the giraffe.

A large amount of repair work and painting was done on the larger metal structures. The frame work of the great flight cage, exterior cages of the lion house and antelope house, and fences of the bear yard were painted, as well as much miscellaneous painting done throughout the park.

The electric pump that was purchased from the 1926 appropriation was installed at the central boiler house and a new and larger pipe connection made from the pump to the hippo, tapir, and alligator pools, greatly improving the supply of warmed water.

The electric service line was extended to the restaurant and electric refrigeration installed—the latter without expense to the park.

A new public walk was built from the junction of the roads to the lion house.

Preliminary to the building of the new bird house, an area about 250 feet square was cleared. In clearing the required space it was necessary to remove a number of large trees—mostly poplars. These were cut into saw-log lengths and converted into lumber.

A service road about 600 feet long was built to the site of the bird house from the new highway on the west side of the park. This road is of tar-bound macadam. It was found necessary to put in an unusually deep stone base for this road because of soft ground, and in view of the fact that heavy hauling would be done over it in bringing materials for the building, and later, bringing coal and other supplies. The sewer and water systems of the park were extended to the site.

A passenger automobile was purchased second hand, and a 1-ton truck was bought for light work about the grounds. A G. M. C. 1½-ton "light aviation" truck chassis was received by transfer.

This was equipped in the park shop with a dumping body, tires, and other necessary fittings and is very useful for heavy hauling.

Food cost somewhat more than during the previous year, owing mainly to increase in price of horse meat. This increase seems likely to be permanent.

NEW BIRD HOUSE

The firm of Arthur L. Smith was awarded the contract for the new bird house by the District architect, and construction was begun on the building in the late spring. The work of grading and laying foundations progressed satisfactorily. Brick work is being executed and the prospects are that the house will be ready for the installation of the bird collection in early spring.

Since many years ago when the Zoological Park received an appropriation of $10,000 to build an elephant house, swimming pool and a yard, the park has never until the past year received an appropriation to construct an exhibition building for animals. This bird house, which has been sadly needed for many years, will be an impressive improvement to the park. The birds will live under modern hygienic conditions and will make an exceedingly fine exhibit.

NEEDS OF THE ZOO

> To a large extent, the animals have still to be kept in temporary quarters which are insufficient and unsuitable, and are costly to maintain because of the repairs which are constantly required.

This statement, which was made in the report for 1910 and repeated from year to year in annual reports, applies even more to-day. While our collection is one of the finest in America, though being rapidly surpassed by six other zoos, the park itself is probably the finest naturally of any zoo in the world; the climate is particularly healthy for animals, which has been proved by numerous records for longevity made in the park, but our buildings are entirely unsuitable and a source of continual unfavorable comment on the part of visitors.

We have a definite building program for structures necessary for the proper housing and exhibition of our stock. These are a reptile and batrachian house, a small mammal house, and a pachyderm house. The construction of these three buildings would enable us to reorganize such as we have now and to tear down other structures constructed originally as temporary makeshifts and which are absolutely unsuitable for the purposes for which they are now used. This year we requested in our annual estimates funds for the construction of a reptile house.

Reptile house.—Ever since 1910 appeals have been made for an exhibition house to contain reptiles, batrachians, and insects. In addition to having probably more educational value than any other

exhibition, such a house has always been most popular with the public in zoos where they exist; so popular, in fact, that in certain zoological parks where admission is required, an extra admission is charged for entry into the reptile building. Here in Washington, visitors repeatedly ask the location of such a building.

Despite the fact that the park management makes no particular attempt to get reptiles, our collection at present consists of nearly 400 specimens representing many rare and valuable species. Among them is a notable collection of the now almost extinct Galapagos Island tortoise, represented here by six specimens belonging to three species. During the winter these are kept in a gloomy room not on exhibition and in a situation crowded and otherwise unsuited to their well-being. The majority of other reptiles in the park are kept in the same building in small boxes.

A request has been made in the estimates for appropriations for such a building in which are to be exhibited not only reptiles and batrachians but also insects and a collection of small tropical fishes.

CONCESSIONS

Practically all zoological gardens maintain refreshment stands and restaurants, and the profits from these are used to purchase animals for the collection. The control by the National Zoological Park of a limited number of concessions would be a distinct benefit to the public in two ways—the service would be enlarged and greatly improved, and the entire profit from the concessions would be used to purchase additional specimens for the exhibition collection.

Respectfully submitted.

W. M. Mann, *Director.*

Dr. C. G. Abbot,
Acting Secretary, Smithsonian Institution.

APPENDIX 7

REPORT ON THE ASTROPHYSICAL OBSERVATORY

Sir: The Astrophysical Observatory was conducted under the following passage of the independent offices appropriation act approved April 22, 1926:

Astrophysical Observatory: For maintenance of the Astrophysical Observatory, under the direction of the Smithsonian Institution, including assistants, purchase of books, periodicals, and apparatus, making necessary observations in high altitudes, repairs and alterations of buildings, preparation of manuscripts, drawings, and illustrations, traveling expenses, and miscellaneous expenses, $31,180, of which amount not to exceed $27,840 may be expended for personal services in the District of Columbia.

The observatory occupies a number of frame structures within an inclosure of about 16,000 square feet south of the Smithsonian administration building at Washington, a cement observing station and frame structure for observers on a plot of 10,000 square feet leased from the Mount Wilson Observatory, and an observing station on Table Mountain, Calif. This last station, provided by Mr. John A. Roebling, includes a tunnel for instruments, small structures for the field director and for the assistant, a shop, and a garage.

The Astrophysical Observatory also defrays a part of the cost of the maintenance of the observing station at Montezuma, Chile, which was erected in 1920, with means furnished by Mr. Roebling. The constructions there comprise a tunnel for instruments, a small structure for observers, shop, garage, and a telephone line 12 miles to Calama.

The present value of the buildings and equipment for the Astrophysical Observatory owned by the Government is estimated at $50,000. This estimate contemplates the cost required to replace the outfit for the purposes of the investigations.

WORK AT WASHINGTON

(*a*) *Radiometer*.—With the cooperation of the Bureau of Standards, whose glass blower, Mr. Sperling, made the difficult glass work needed with glass-sealed optical windows, preparations were made to construct a very sensitive radiometer. It will be recalled that in October, 1923, Dr. C. G. Abbot employed a radiometer prepared by Nichols and Tear, and, observing with the 100-inch telescope on Mount Wilson, obtained the first energy-spectra of stars ever measured with heat-recording apparatus. In 1924 he

attempted to improve on these first results by constructing a lighter system, using flies' wings to prepare the vanes of the instrument. But he found that at the air pressure required to give a good radiometer deflection, the system was damped into such sluggishness as to be useless. At the suggestion of Doctor Anderson of Mount Wilson Observatory, Doctor Abbot proposed to substitute hydrogen for air, hoping to get equal sensitiveness and much less damping. As hydrogen would be contaminated by air leakage, or cock grease, or mercury vapor if connected with an air pump, as usual, he proposed to seal up the suspended system in glass like an X-ray tube, having first exhausted the glass case as completely as possible, and filled in pure hydrogen (through a liquid air trap) to the desired pressure.

The necessity of rotating the suspended system with reference to the glass case and its optical windows offered difficulties. However, this was accomplished by including within the case a train of gearing ending in a little horseshoe magnet, which could be rotated by another magnet from without. The reduction of speed from the magnet to the suspension system was in all nearly 10,000-fold, so that a little reversible electric motor, with cone drive, was arranged to drive the outside magnet through so many thousands of turns. All of these contrivances were constructed by Mr. Kramer under Doctor Abbot's direction, but the actual expedition to Mount Wilson did not go forward until July, 1927, and will be described in the report of 1928. It may be worth while to add, however, that Mr. Aldrich tested occasionally for 10 months, by weighings, the evaporation of a large surface of beeswax laid down on thin mica. The loss was so very slight that this substance was found quite suitable to fasten the parts of the radiometer suspension without fear of appreciably contaminating the hydrogen by mixture of its heavy molecules.

(*b*) *Pyrheliometer.*—Although the Californian and the South West African equipments had been supplied with silver-disk pyrheliometers with very long vestibules to cut down the effect of atmospheric radiation immediately surrounding the sun, and though all of our observatories have been equipped with half-second pendulums to reduce error in time observations at the pyrheliometers, yet we are seeking a degree of accuracy so high that an attempt seemed desirable to devise a new type of pyrheliometer in which errors would be still more reduced. This instrument was not entirely completed at the close of the period of this report, and its performance will be described in the report for 1928.

(*c*) *Revision of observations.*—The important work of revision of solar radiation measurements mentioned in last year's report was prosecuted vigorously during the fiscal year. A complete re-reduc-

tion of all Montezuma observations from 1923 to date, including the measurement of plates for nearly 150 days of fundamental observation by Langley's method, and also the setting up of a new system of reduction for short-method observations, was completed in May, 1927. The new results, while differing on the average by only a small fraction of 1 per cent from the preliminary ones, are undoubtedly of much greater weight, and may now be regarded as definitive. A full description of the processes and the reasons for them will eventually be published.

A similar study of all Table Mountain observations is going on, and, when completed, definitive observations will be published from that station also.

Readers may understand the necessity of these revisions of solar radiation observations by recalling that in astronomy the late Prof. Lewis Boss spent many years in a revision of all high-class observations of the positions of stars, and introduced numerous corrections to the individual observations, based on extensive statistical study, before he was able to combine the whole study into his "Classical Preliminary General Catalogue." A similar statistical study of our solar observations could not be made until several years of homogeneous measurements were available. It would have been better to have waited for 10 years before making it, but the urgent demands of meteorologists for our solar observations have induced us to try to put the matter in definitive form thus early.

(*d*) *Smithsonian exhibition of February 11, 1927.*—In connection with the conference of eminent men on the future of the Smithsonian Institution, the Astrophysical Observatory, as well as other departments, was represented by an exhibit of working instruments, diagrams, and photographs. In order to give as complete and striking a picture as possible of the purposes and attainments of the observatory a very considerable amount of time of the director, of Mr. Aldrich, and of Mr. Kramer, was devoted thereto.

FIELD WORK

(*a*) *Table Mountain, Calif.*—This observatory, which by Mr. John A. Roebling's generosity was erected in the autumn of 1925 to replace that on Mount Harqua Hala, has been in continuous observation of the solar constant of radiation during the fiscal year. While the number of days available for observation does not very greatly exceed the number at Harqua Hala, the quality of these days, especially in the months of June, July, August, and September, is immensely superior. On one occasion in the autumn of 1926 Mr. Moore was able to observe at Table Mountain on 71 consecutive days, which is by far the maximum record for any of our stations.

As stated above, a definitive reduction of all Table Mountain observations is being vigorously pushed.

(*b*) *Montezuma, Chile.*—This, our best solar constant station, was also in continuous observation during the entire year. Its daily results were published on the United States weather maps of the next following days; also, telegraphic advices were sent daily to the Argentine Government, and to Dr. Julio Bustos Navarette, who publishes a monthly meteorological bulletin containing them.

As stated above, a definite re-reduction of the Montezuma work has been completed, and the results are now being published in final form.

At the suggestion of Doctor Dobson, of Oxford, England, a copy of his atmospheric ozone measuring apparatus has been installed at Montezuma, and its daily results are forwarded to Doctor Dobson for reduction and publication.

(*c*) *Mount Brukkaros, South West Africa.*—The solar radiation expedition of the National Geographic Society, in cooperation with the Smithsonian Institution, was fully equipped and sent forward in August, 1926. Meanwhile, the observatory itself was being prepared by Mr. Dryden, of Keetmanshoop, South West Africa, under Government auspices. A little later a telephone line was installed by Colonel Venning, director of posts and telegraph, of Windhoek.

The expedition (W. H. Hoover, director, F. W. Greeley, assistant) reached the mountain in October, 1926, made preliminary observations in November, and began regular daily observing in December.

It is yet too early to decide how satisfactory atmospheric conditions at this observatory will prove to be. During a considerable part of the time they have been first class. Old residents maintain that during the unfavorable time the weather has been unusual, and that other years will prove much better. This view is supported to some extent by the weather of Montezuma, Chile, which seems to be in some degree parallel. Atmospheric conditions have undoubtedly been unusually bad at Montezuma during the times when Mount Brukkaros reported unfavorable conditions.

Personnel.—The present personnel of the Astrophysical Observatory is as follows:

Director,[1] Dr. C. G. Abbot, Washington.
Field director, Mr. A. F. Moore, Table Mountain.
Field director, Mr. H. B. Freeman, Montezuma.
Field director,[2] Mr. W. H. Hoover, Mount Brukkaros.
Research assistant, Mr. F. E. Fowle, Washington.
Research assistant, Mr. L. B. Aldrich, Washington.
Field assistant,[2] Mr. H. H. Zodtner, Table Mountain.
Field assistant,[2] Mr. E. E. Warner, Montezuma.

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[1] This compensation was defrayed in part from private funds.
[2] This compensation was defrayed in part or wholly from private funds.

Field assistant, Mr. F. A. Greeley, Mount Brukkaros.
Computer, Mrs. A. M. Bond, Washington.
Computer, Miss M. A. Marsden, Washington.
Computer,[2] Miss M. C. Rhoderick, Washington (temporary).
Instrument maker, Mr. A. Kramer, Washington.
Librarian,[2] Mrs. M. L. Reed, Washington (temporary).
Librarian,[2] Mrs. A. E. Blanchard, Washington (temporary).
Librarian,[2] Miss M. B. Ladd, Washington (temporary).
Librarian,[2] Miss C. S. Gunther, Washington (temporary).

Summary.—The work of the year was mainly in continuation of accurate observations of the solar constant of radiation. A new cooperating observatory in South West Africa was installed at the cost of the National Geographic Society. Improved apparatus and procedure has led to a higher standard of accuracy in all the observatories than ever before.

Gratifying correlations with other results are appearing. Thus Doctor Pettit's observations of ultra-violet solar radiation, while showing extreme variations of at least a hundred per cent, are closely in proportion with the small changes found in total solar radiation by the Smithsonian observers. Doctor Austin, too, finds a very high correlation between solar constant changes and the reception of long range radio.

Finally, a remarkable regular periodicity of 25⅔ months has been found by Dr. C. G. Abbot in the solar variation itself, which, during the years 1920 to 1927, has joined with the sun-spot cycle to account for almost the whole change in monthly mean solar constant results. If this persists in future years, it may become possible to forecast at least two years in advance the principal solar changes, and whatever of importance may prove to hang thereon.

Respectfully submitted.

C. G. Abbot,
Director, Astrophysical Observatory.

To the Acting Secretary,
Smithsonian Institution.

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[2] This compensation was defrayed in part or wholly from private funds.

APPENDIX 8

REPORT ON THE INTERNATIONAL CATALOGUE OF SCIENTIFIC LITERATURE

Sir: I have the honor to submit herewith the following report on the operations of the United States regional bureau of the International Catalogue of Scientific Literature for the fiscal year ending June 30, 1927:

Since 1921, when war conditions in the majority of the 33 countries cooperating in the enterprise made it impossible for them to provide their quota of the funds needed to continue publication, it has been the aim of this bureau to collect and record the data necessary to enable it to supply, when publication is resumed, an index to the scientific publications of the United States and its possessions, and this routine has been the principal part of its work during the year.

A partial list of the scientific journals of 25 of the countries cooperating in the catalogue was published in 1903 and a supplementary list in 1904, bringing the number of countries represented up to 27 and making a total of 5,496 titles, as shown in the following table:

List of journals

	1903	1904	Total		1903	1904	Total
Austria	0	536	536	New South Wales	7	1	8
Belgium	171	2	173	New Zealand	1	0	1
Canada	45	0	45	Norway	30	6	36
Colony of the Cape of Good Hope	5	0	5	Poland	65	0	65
Denmark	39	1	40	Portugal	19	0	19
Finland	31	2	33	Russia	409	47	456
France	900	11	911	South Africa	0	15	15
Germany	1,297	86	1,383	South Australia	6	0	6
Greece	11	0	11	Sweden	62	1	63
Holland	66	2	68	Switzerland	126	126	252
Hungary	21	14	35	United Kingdom	471	16	487
India and Ceylon	30	1	31	United States of America	408	51	459
Italy	252	41	293	Victoria (Australia)	20	3	23
Japan	42	0	42	Total	4,534	962	5,496

The number 459 does not represent all the American journals actually indexed by this bureau. The purpose of the list being primarily to explain the abbreviations used in the catalogue, many State publications which were abbreviated in a uniform manner were not listed separately, while unabbreviated titles were omitted alto-

gether. Although no supplementary lists have been published since 1904, many journals have been added since that time. Pending the resumption of publication, it was felt that the United States list should be entirely revised, and the collection of necessary data for this work was begun during the year. When the list is completed, it is expected to publish it in pamphlet form, as no such list now exists, although a general need for it is felt among librarians and students of science quite independently of the requirements of the International Catalogue.

In 1922 the International Convention of the Catalogue at its meeting in Brussels passed a resolution to keep the organization in being until financial conditions should make it possible to resume publication. Since that time it has been the aim of this bureau to do its part in continuing the work of the catalogue. Each year, when Congress is asked for the appropriation for maintenance, the explanation is made that although nothing is now being published it is felt that, in view of the recognized need of such a catalogue, the United States should do its utmost to keep the present organization alive. This is the more important in order that the labors of so many eminent men, who in the beginning succeeded in the very difficult task of securing the cooperation of 33 countries, should not be lost, and also that as soon as a sufficient endowment is had, or international financial conditions become normal, the original organization can again take up the work at the point where war conditions made suspension necessary.

Very respectfully,

LEONARD C. GUNNELL,
Assistant in Charge.

DR. CHARLES G. ABBOT,
Acting Secretary, Smithsonian Institution.

APPENDIX 9

REPORT ON THE LIBRARY

SIR: I have the honor to submit the following report on the activities of the library of the Smithsonian Institution for the fiscal year ended June 30, 1927:

WHAT THE LIBRARY IS

Perhaps it will not be amiss if I explain at the outset what the Smithsonian library is. It is the library, now numbering about 700,000 volumes, pamphlets, and charts, to say nothing of many thousands of volumes awaiting completion, that has grown up since 1846 around the activities of the Institution. As these activities have been various, the library naturally falls into several divisions, but all with one central purpose—that of assisting the Institution in the increase and diffusion of knowledge.

Chief among these divisions are the Smithsonian deposit in the Library of Congress, which is the main library of the Institution, and the library of the United States National Museum, which consists largely of material having to do with the different branches of natural science represented in the Museum. The other divisions are the office library, the technological library, the Langley aeronautical library, and the libraries respectively of the Astrophysical Observatory, the Bureau of American Ethnology, the National Gallery of Art, the Freer Gallery of Art, and the National Zoological Park. Together these comprise the Smithsonian library. They are, of course, distinct working units, each serving its own end in its own place, but all contributing toward the realization of a common ideal.

For the sake of making the material in these 10 divisions more completely and centrally available, a union catalogue of their collections is being prepared, to be kept in the Smithsonian Building. This will be one of the main pieces of work of the library staff for years to come, and one of the most serviceable to the Institution.

CHANGES IN STAFF

Few changes occurred in the staff during the year. This was most gratifying, as permanence of tenure on the part of trained and willing employees makes for efficiency, especially in so highly technical an organization as a scientific library.

One of the two positions of minor library assistant granted by Congress as of July 1, 1926, was filled by the promotion of Miss Agnes Auth; the other was filled temporarily until toward the close of the year, when Mrs. Mary Arnold Baer, library aid, was recommended for it.

In the position of assistant messenger Mr. William Helvestine was succeeded by Mr. Robert Mooney, and he in turn by Mr. Herschel Chappell. Both Mr. Helvestine and Mr. Mooney resigned to accept higher positions elsewhere in the Institution.

In the course of the year the following persons were employed temporarily: Mrs. Madaline D. Amphlett, Mrs. Adella E. Blanchard, Mr. Clarence Gunther, Miss Elisabeth Hobbs, Mrs. Dorothy P. Hulsizer, Mr. Walter Jaeger, Miss Mary Ladd, Mrs. M. Landon Reed, Mr. Giles E. Taggart, Miss Helen Turnbull, and Mrs. Victoria B. Turner.

To expedite the carrying out of the plans of reorganization begun three years ago, there is urgent need of two more positions of the rank of assistant librarian—one for a head of the accessions department, the other for a head of the catalogue department. These, with the head of the reference department, already appointed, will direct, under the librarian, the three general activities of the library, namely, acquiring material, making it available, and using it. It is earnestly hoped that the two positions referred to can be created without delay.

EXCHANGE OF PUBLICATIONS

The growth of the library, although dependent somewhat upon purchase and gift, is dependent chiefly upon the exchange of publications between the Institution and its branches and other learned institutions and societies throughout the world. These publications come to the library direct, or through the international exchange service, which is administered by the Institution. During the last fiscal year 31,647 packages, of one or more publications each, came by mail, and 7,459 through the exchange. This was an increase of more than 1,200 packages over the year before, and testified to the generous response made to the letters prepared by the library asking for numbers missing from its sets, or proposing or accepting exchange relations with new societies. In all, 1,604 letters were written—a gain of nearly 400 over the previous year. Most of these had to do with the exchange of publications. After the 39,106 packages had been opened, the items were stamped, entered, and sent to the appropriate divisions of the library, but chiefly to the Smithsonian deposit in the Library of Congress and the library of the National Museum.

As usual, dissertations were received from various universities, such as Basel, Berlin, Bern, Bonn, Copenhagen, Delft, Frankfurt, Giessen,

Graz, Greifswald, Johns Hopkins, Leipzig, Warburg, Neuchâtel, Pennsylvania, Strasbourg, and Zürich; and from technical schools at Berlin, Charlottenburg, Delft, and Freiberg.

SMITHSONIAN DEPOSIT

As has been said, the main division of the library of the Institution is the Smithsonian deposit in the Library of Congress. This is, of course, distributed according to classification, but because of its prevailingly scientific nature it is chiefly in the Smithsonian division, which was established in 1900 to take care of it, in common with the scientific publications belonging to the Library of Congress.

This collection, which began with the deposit of 40,000 volumes by the Smithsonian Institution in 1866, under authorization of an act of Congress, has grown by almost daily additions from the Institution until it has come to hold a foremost place among libraries of its kind, being especially rich in the reports, proceedings, and transactions of learned institutions and societies the world over.

The publications sent to the deposit by the Institution during the last fiscal year numbered 5,790, of which 4,046 were complete volumes, 329 parts of volumes, 147 pamphlets, and 268 charts. These represented a gain over the year before of 702, more than one-half of which were complete volumes. Documents of foreign governments, chiefly statistical in character, to the number of about 7,500, were also sent, without being stamped or entered, to the document division of the Library of Congress. In response to special requests from the Smithsonian division, the periodical division, and the order division of the Library of Congress for publications needed to complete sets in the deposit, the Smithsonian library was able to obtain by exchange 495 volumes and 602 parts of volumes, including title-pages and indexes.

OFFICE LIBRARY

The office library is made up of the society publications that are kept in the Smithsonian Building, the art-room collection, the employees' library, and various books, mainly of a reference nature, assigned for special use to other divisions of the library or to the administrative offices of the Institution. To this library were added during the year 146 volumes, 3 parts of volumes, and 10 pamphlets. The circulation was 2,228, of which 1,941 were magazines. Many volumes were consulted in the reference room.

Among the noteworthy gifts to the library were the following: New Coptic Texts from the Monastery of St. Macarius, and the Monastery of Epiphanius at Thebes, from the Metropolitan Museum of Art; the Catalogue of the Philatelic Library of the Earl of Crawford, together with a supplement, compiled by E. D. Bacon and presented

by the Philatelic Literature Society of London; Nomenclator Animalium Generum et Subgenerum, from the Preussische Akademie der Wissenschaften—a publication not regularly sent in exchange, but which the Academy was good enough to present to the Smithsonian Institution; Le Trésor de Pétrossa, from the Academia Romana; and Denkmaller aus Aegypten und Aethiopen, in 12 volumes, by C. E. Lepsius, from Mrs. George Cabot Lodge. Another important gift was a copy of Billeder af Nordens Flora Med Tekst af A. Mentz og C. H. Ostenfeld—a work in which the authors are doing for Scandinavian wild flowers what Mrs. Charles D. Walcott, in her well-known North American Wild Flowers, is doing for the flowers of our own country. This interesting work was presented to the Institution by the authors, through the good offices of Dr. Oskar Thyregod, librarian of the Industriforeningens Bibliotek, Copenhagen.

But the outstanding gift of the year was that of the John Donnell Smith botanical collection of 1,600 volumes. This library was really presented to the Institution in 1905, but only part of it was transferred to Washington before last year. Now it is all shelved in the west end of the Smithsonian Building, awaiting the completion of a special alcove in the section of botany, where it will be deposited, that it may be easily available to the scientists there. This is one of the most valuable gifts ever made to the Smithsonian library. It includes books not duplicated in Washington, and at least one rare work of which, so far as the librarian knows, there is only one other copy in the United States. This is a volume by Gomez Ortega, published at Madrid in 1797, which contains the first published descriptions of many important plants of Mexico. The library is particularly rich in works on tropical American plants, especially those of Central America. Many of the books were obtained abroad and are beautifully bound. Each volume bears a distinctive plate with the name of the donor. In 1908 a catalogue of the collection was prepared by Miss Alice Cary Atwood, of the Department of Agriculture, and published by the Institution.

The work done on the general catalogue of the Smithsonian library (not including that in connection with the library of the Astrophysical Observatory, spoken of elsewhere), which is kept in the office reading room, was as follows:

Volumes catalogued	3,922
Volumes recatalogued	134
Charts catalogued	221
Cards typed	1,697
Library of Congress cards filed	406
New authors added	520

MUSEUM LIBRARY

During the year 2,492 volumes and 1,299 pamphlets were added to the library of the National Museum, representing an increase in accessions of more than 20 per cent over the year before, and giving the library a total of 69,300 volumes and 105,716 pamphlets. Most of the accessions came, of course, by exchange; others came by gift, especially from the Library of Congress, which was generous enough to send from its collection of duplicates 512 volumes and 1,926 parts of volumes needed by the library toward completing its sets. Important gifts were also made by the late Secretary Walcott, Dr. W. H. Holmes, and Dr. C. W. Richmond. Some of the other donors were Assistant Secretary Wetmore, Dr. J. M. Aldrich, Mr. A. H. Clark, the late Dr. W. H. Dall, Dr. O. P. Hay, Dr. Walter Hough, Dr. Aleš Hrdlička, Mr. N. M. Judd, Dr. W. R. Maxon, Dr. G. P. Merrill, Dr. G. S. Miller, jr., Mr. A. J. Olmsted, Miss M. J. Rathbun, and Mr. J. H. Riley.

In the course of the year 12,274 parts of periodicals were entered, 710 volumes and 948 pamphlets were catalogued, and 4,818 cards were added to the shelf list. The loans to members of the scientific staff totaled 4,316, of which 1,721 were borrowed from the Library of Congress and 137 elsewhere. The other loans numbered 198, made chiefly to Government libraries and libraries outside of Washington. Thousands of publications were consulted in the reference room, both by members of the staff and by other research workers, including some from foreign countries.

The number of sectional libraries in the Museum is now 36. As has been indicated elsewhere in this report, progress was made during the year in supplying numbers missing from their sets, particularly of society publications, and in cataloguing several of their special collections. The sectional libraries are as follows:

Administration.
Administrative assistant's office.
American archeology.
Anthropology.
Biology.
Birds.
Botany.
Echinoderms.
Editor's office.
Ethnology.
Fishes.
Foods.
Geology.
Graphic arts.
History.
Insects.
Invertebrate paleontology.
Mammals.
Marine invertebrates.
Mechanical technology.
Medicine.
Minerals.
Mineral technology.
Mollusks.
Old World archeology.
Organic chemistry.
Paleobotany.
Photography.
Physical anthropology.
Property clerk's office.
Textiles.
Vertebrate paleontology.
Wood technology.
Reptiles and batrachians.
Superintendent's office.
Taxidermy.

TECHNOLOGICAL LIBRARY

The technological library, which is located in the old Museum Building, concerns itself chiefly with the useful arts and industries. During the year the work of reorganizing its material was considerably advanced. The shelf list was finished by the addition of 2,500 cards, and an excellent beginning made on the inventory. Many duplicates were removed to the west stacks of the Smithsonian Building, together with a large number of Government publications and publications of various States not needed in the library. These will be disposed of later. Their removal from the old Museum has materially increased the space available for collections necessary to the work of the curators. The loans numbered 450.

ASTROPHYSICAL OBSERVATORY LIBRARY

The library of the Astrophysical Observatory, which is housed partly in the Smithsonian Building and partly in the observatory at the rear of this building, consists of 3,637 volumes and about 2,700 pamphlets, chiefly on astrophysics and meteorology. It is one of the most important of the smaller divisions of the Smithsonian library, being of especial value in connection with the well-known researches in solar radiation that are being carried on by the Institution. This library received particular attention during the past year. A shelf list was prepared, an inventory taken, and its material completely rearranged. Many gaps in its sets were filled. A notable beginning was also made on a dictionary catalogue, with subject cards and analyticals, under the direction of a person of long experience in the Library of Congress. A detailed record of this work follows:

Volumes catalogued	548
Pamphlets catalogued	1,032
Charts catalogued	14
Library of Congress cards filed	6,918
Cards typed	2,298

The library was increased by 137 volumes, 16 parts of volumes, and 22 pamphlets. The number of volumes bound was 49. The loans are included among those of the office library.

BUREAU OF AMERICAN ETHNOLOGY LIBRARY

The library of the Bureau of American Ethnology, which is in the Smithsonian Building, consists almost exclusively of works on anthropology, particularly those pertaining to the American aborigines, and covers especially the linguistics, history, archeology, myths, religion, arts, sociology, and general culture of the American Indian. It contains 27,141 volumes and 15,937 pamphlets. In its special data files are manuscript material, photographs, Indian vocabularies, etc. The activities of this library for the last fiscal

year are described in the report of the chief of the bureau, by whom the library is administered.

LANGLEY AERONAUTICAL LIBRARY

In my last report, I mentioned that the aeronautical collection of the Institution was to be raised to the dignity of a division of the Smithsonian library, and named after Samuel Pierpont Langley, the third secretary, whose researches and experiments marked the establishment of aeronautics in the United States on a scientific basis. This has now been done, and the Langley aeronautical library, because of the rapidly developing interest in aeronautics, bids fair to become one of the prominent units of the Smithsonian library. While it is still comparatively small, numbering only about 1,600 volumes and 700 pamphlets, together with a large number of photographs and newspaper clippings, it includes many rare items, some of which were in the original nucleus as it came from Secretary Langley, and others among the additions made since by Alexander Graham Bell, Octave Chanute, and James Means. During the fiscal year just closed a shelf list was made for this library, an inventory was taken, and many parts missing from its sets were supplied. The accessions numbered 41. A catalogue of the library will soon be prepared.

NATIONAL GALLERY OF ART LIBRARY

The library of the National Gallery of Art, at present housed in the Natural History Building pending transfer to the special building which it is hoped will soon be erected for the gallery, is an important division of the Smithsonian library. While it totals only 704 volumes and 786 pamphlets, these have been so carefully chosen that the collection forms a valuable nucleus for the larger library in prospect. The collection was increased during the past year by 123 volumes, 738 parts of volumes, and 120 pamphlets. Gifts worthy of particular mention were made by Mr. J. U. Perkins and by Dr. William H. Holmes, director of the gallery. The latter's gift included two books of unusual interest—one a copy of the "Holmes Anniversary Volume," consisting of anthropological essays presented to Doctor Holmes by his friends and colaborers in honor of his seventieth birthday; the other a volume of 160 manuscript letters written by Doctor Holmes's friends in America and abroad in recognition of his eightieth birthday.

FREER GALLERY OF ART LIBRARY

The library of the Freer Gallery of Art is restricted to the interests represented by the collections of art objects pertaining to the arts and cultures of the Far East, India, Persia, and the nearer East;

by the life and works of James McNeil Whistler and of certain other American painters whose pictures are owned by the gallery; and, further, to a very limited degree, by the Biblical manuscripts of the fourth and fifth centuries, which, as the possession of the Freer Gallery, are known as the Washington manuscripts. The library was increased during the year by 37 volumes and 151 pamphlets. It now has a total of 2,912 volumes and 2,519 pamphlets, many of which are in the Chinese and Japanese languages.

NATIONAL ZOOLOGICAL PARK LIBRARY

The library of the National Zoological Park comprises about 1,200 volumes and 300 pamphlets on animals and other subjects of interest to the park. It increased the past year by 21 volumes.

SUMMARY OF ACCESSIONS

The accessions for the year, with the exception of those to the library of the Bureau of American Ethnology, may be summarized as follows:

Library	Volumes	Pamphlets and charts	Total
Astrophysical Observatory	137	22	159
Freer Gallery of Art	37	151	188
Langley aeronautical library	30	11	41
National Gallery of Art	123	120	243
National Zoological Park	21		21
Smithsonian deposit, Library of Congress	4,046	415	4,461
Smithsonian office	146	10	156
United States National Museum, including the technological library	2,492	1,299	3,791
Total	7,032	2,028	9,060

An estimate of the number of volumes, pamphlets, and charts in the Smithsonian library, not including those in the library of the Bureau of American Ethnology, on June 30, 1927, was as follows:

Volumes	521,103
Pamphlets	141,285
Charts	24,155
Total	686,543

This number does not include the many thousands of parts of volumes in the library awaiting completion of the volumes.

SPECIAL ACTIVITIES

In addition to the regular work of the year, several special tasks were undertaken.

The intensive effort to complete the broken sets, both in the main collections and in the sectional libraries, begun the previous year, was

continued with excellent results, and thanks are due the Library of Congress and hundreds of learned societies and institutions the world over for their generous response to requests for numbers needed by the library.

Decided progress was made on the union catalogue, especially by the splendid work done by two members of the staff toward cataloguing the library of the Astrophysical Observatory. A beginning was also made in cataloguing some of the special collections in the sectional libraries, but, for lack of help, this work could not be carried far.

An important piece of work was the preparation of nearly 2,000 volumes for binding, of which 1,439 were sent to the bindery for the National Museum, and 49 for the Astrophysical Observatory. The rest will be sent early in the next fiscal year.

The work of reorganizing the technological library was continued with vigor, but, owing to the increasing difficulty of the task and the lack of help, was not completed. It will require at least another year of special effort.

Thousands of duplicates from the Smithsonian deposit and other divisions of the library were taken to the west stacks and filed, preparatory to being listed and exchanged. This work of bringing together the duplicates in the library is now nearing completion.

Another task that required no little time and care was the final checking of the holdings in the various divisions of the library for the forthcoming union list of serials.

Still another was the filing of 30,866 cards in the alphabetic and methodical sets of the Bibliographicum Concilium in the Museum library. This was almost twice the number filed the year before.

There was increased opportunity during the year for lending material on semipermanent charge to institutions where research is being conducted. A notable instance of this was the loan to the Johns Hopkins University of 104 titles from the Lacoe collection in paleobotany. Other loans of especial interest, as the items were rare in this country, were made to the University of Wisconsin and the California Academy of Sciences.

Mention might be made, too, that the library prepared an exhibit of books representing the different interests of the Institution and its branches, for the conference on the future held at the Institution in February.

CONCLUSION

On the whole, the year was one of progress toward solving the problems which have arisen in connection with the work of reorganizing the library that was begun three years ago. But the prog-

ress would have been far greater if funds had been at hand for buying more of the books and periodicals needed by the curators, for supplying in the standard sets the missing numbers that can not be obtained by exchange, and for employing enough trained workers not only to carry on more adequately the current work of the library but in particular to make available at the earliest possible moment the thousands of volumes and pamphlets now lying useless on the shelves, and to expedite the making of the union catalogue of which the Institution stands so much in need. For these purposes funds should be provided as soon as possible.

Respectfully submitted.

William L. Corbin, *Librarian.*

Dr. Charles G. Abbot,

Acting Secretary, Smithsonian Institution.

APPENDIX 10

REPORT ON THE PUBLICATIONS

Sir: I have the honor to submit the following report on the publications of the Smithsonian Institution and the Government bureaus under its administrative charge during the year ending June 30, 1927:

The Institution proper published during the year 10 papers in the series of Smithsonian Miscellaneous Collections, 1 annual report, and pamphlet copies of the 27 articles contained in the report appendix, and 3 special publications. The Bureau of American Ethnology published 2 bulletins and 1 special publication. The United States National Museum issued 1 annual report, 1 volume of proceedings, 7 complete bulletins, 3 parts of a bulletin, 1 complete volume, and 5 parts of four volumes in the series Contributions from the United States National Herbarium, and 55 separates from the Proceedings.

Of these publications there were distributed during the year 182,846 copies, which included 68 volumes and separates of the Smithsonian Contributions to Knowledge, 18,199 volumes and separates of the Smithsonian Miscellaneous Collections, 24,775 volumes and separates of the Smithsonian annual reports, 17,178 Smithsonian special publications, 110,580 volumes and separates of the various series of National Museum publications, 10,711 publications of the Bureau of American Ethnology, 74 publications of the National Gallery of Art, 66 volumes of the Annals of the Astrophysical Observatory, 40 reports of the Harriman Alaska Expedition, 779 reports of the American Historical Association, and 376 publications presented to but not issued directly by the Smithsonian Institution or its branches.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

Of the Smithsonian Miscellaneous Collections, volume 73, 1 paper was issued; volume 75, 1 paper; volume 78, 6 papers; volume 80, 2 papers; in all, 10 papers.

VOLUME 73

No. 4. Opinions Rendered by the International Commission on Zoological Nomenclature. Opinions 91 to 97. October 8, 1926. 30 pp. (Publ. 2873.)

VOLUME 75

No. 4. Cambrian Geology and Paleontology, V. No. 4. Pre-Devonian Sedimentation in Southern Canadian Rocky Mountains. By Charles D. Walcott. April 2, 1927. Pp. 147–173, pl. 25, text figs. 14–22. (Publ. 2870.)

VOLUME 78

No. 3. The Classification and Distribution of the Pit River Indian Tribes of California. By C. Hart Merriam. December 31, 1926. 52 pp., 27 pls. (Publ. 2874.)

No. 4. Solar Activity and Long-Period Weather Changes. By Henry Helm Clayton. September 30, 1926. 62 pp., 13 text figures. (Publ. 2875.)

No. 5. The Distribution of Energy Over the Sun's Disk. By C. G. Abbot. October 12, 1926. 12 pp., 1 pl., 1 text fig. (Publ. 2876.)

No. 6. The Lyell and Freshfield Glaciers, Canadian Rocky Mountains, 1926. By J. Monroe Thorington. February 5, 1927. 8 pp., 12 pls. (Publ. 2911.)

No. 7. Explorations and Field Work of the Smithsonian Institution in 1926. April 21, 1927. 259 pp., 247 figs. (Publ. 2912.)

No. 8. The Flora of Barro Colorado Island. By Paul C. Standley. May 20 1927. 32 pp. (Publ. 2914.)

VOLUME 80

No. 1. Morphology and Mechanism of the Insect Thorax. By R. E. Snodgrass, Bureau of Entomology. June 25, 1927. 108 pp., 44 text figs. (Publ. 2915.)

No. 2. A Group of Solar Changes. By C. G. Abbot. April 25, 1927. 16 pp., 9 text figs. (Publ. 2916.)

SMITHSONIAN ANNUAL REPORTS

Report for 1925.—The complete volume of the Annual Report of the Board of Regents for 1925 was received from the Public Printer in November, 1926.

Annual Report of the Board of Regents of the Smithsonian Institution, showing operations, expenditures, and condition of the Institution for the year ending June 30, 1925. xii+633 pp., 84 pls., 77 text figs. (Publ. 2836.)

The appendix contained the following papers:

The spiral nebulæ and the structure of space, by Carl Wirtz.
Immensities of time and space, by A. Vibert Douglas.
Certain aspects of high-pressure research, by P. W. Bridgman.
Lightning and other high-voltage phenomena, by F. W. Peek, jr.
Chemical elements and atoms, by G. Urbain.
The manufacture of radium, by Camille Matignon.
The chemistry of solids, by Cecil H. Desch.
Terrestrial magnetism in the twentieth century, by Daniel L. Hazzard.
Some causes of volcanic activity, by Arthur L. Day.
Geology in the service of man, by W. W. Watts.
The yeasts: A chapter in microscopical science, by A. Chaston Chapman.
Tropical cyclones and the dispersal of life from island to island in the Pacific, by Stephen Sargent Visher.
Isolation with segregation as a factor in organic evolution, by David Starr Jordan.
The biological action of light, by Leonard Hill.
Animal life at high altitudes, by Maj. R. W. G. Hingston.
The nest of the Indian tailor bird, by Casey A. Wood.
The needs of the world as to entomology, by L. O. Howard.
From an egg to an insect, by R. E. Snodgrass.

The rôle of vertebrates in the control of insect pests, by W. L. McAtee.
Carnivorous butterflies, by Austin H. Clark.
The potato of romance and of reality, by W. E. Safford.
The relation of geography to timber supply, by W. B. Greeley.
The historical geography of early Japan, by Carl Whiting Bishop.
The excavations of the sanctuary of Tanit at Carthage, by Byron Khun de Prorok.
The Smithsonian Institution.
Sir Archibald Geikie, by Sir Aubrey Strahan.
Ned Hollister (1876–1924), by Wilfred H. Osgood.

Report for 1926.—The report of the executive committee and Proceedings of the Board of Regents of the Institution, and the report of the secretary, both forming parts of the annual report of the Board of Regents to Congress, were issued in pamphlet form in December, 1926.

Report of the executive committee and Proceedings of the Board of Regents of the Smithsonian Institution for the year ending June 30, 1926. 11 pp. (Publ. 2878.)

Report of the Secretary of the Smithsonian Institution for the year ending June 30, 1926. 135 pp. (Publ. 2877.)

The general appendix to this report, which was in press at the close of the year, contains the following papers:

The new outlook in cosmogony, by J. H. Jeans.
Influences of sun rays on plants and animals, by C. G. Abbot.
On the evolution of the stars, by C. G. Abbot.
Excursions on the planets, by Lucien Rudaux.
High-frequency rays of cosmic origin, by R. A. Millikan.
The present status of radio atmospheric disturbances, by L. W. Austin.
Cold light, by E. Newton Harvey.
Scientific work of the Maud expedition, 1922–1925, by H. U. Sverdrup.
The romance of carbon, by Arthur D. Little.
The cause of earthquakes; especially those of the eastern United States, by William Herbert Hobbs.
The loess of China, by George B. Barbour.
A visit to the gem districts of Ceylon and Burma, by Frank D. Adams.
The history of organic evolution, by John M. Coulter.
Barro Colorado Island Biological Station, by Alfred O. Gross.
Geography and evolution in the pocket gophers of California, by Joseph Grinnell.
How beavers build their houses, by Vernon Bailey.
The mosquito-fish (*Gambusia*), and its relation to malaria, by David Starr Jordan.
The effect of aluminum sulphate on rhododendrons and other acid-soil plants, by Frederick V. Coville.
Eastern Brazil through an agrostologist's spectacles, by Agnes Chase.
Our heritage from the American Indians, by W. E. Safford.
The parasite element of natural control of injurious insects and its control by man, by L. O. Howard.
Fragrant butterflies, by Austin H. Clark.
The ritual bullfight, by C. W. Bishop.
The bronzes of Hsin-Chêng Hsien, by C. W. Bishop.

The Katcina altars in Hopi worship, by J. Walter Fewkes.
Omaha bow and arrow makers, by Francis La Flesche.
The National Park of Switzerland, by G. Edith Bland.
Samuel Slater and the oldest cotton machinery in America, by Frederick L. Lewton.
Preventive medicine, by Mark F. Boyd.
William Bateson, by T. H. Morgan.
H. Kamerlingh Onnes, by F. A. Freeth.

SPECIAL PUBLICATIONS

American Silurian Crinoids. By Frank Springer, Las Vegas, New Mexico. Associate in Paleontology, U. S. National Museum. December 20, 1926. 239 pp., 32 pls. Quarto. (Publ. 2871.)

Proceedings of the Conference on the Future of the Smithsonian Institution. February 11, 1927. 88 pp., 12 full-page illus.

Title page and contents, Smithsonian Miscellaneous Collections, vol. 77. 8 pp.

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM

During the year ending June 30, 1927, the Museum published 1 annual report, 1 volume of proceedings, 7 complete bulletins, 3 parts of a bulletin, 1 complete volume and 5 parts of 4 volumes in the series Contributions from the United States National Herbarium, and 55 separates from the proceedings.

The issues of the bulletin were as follows:

Bulletin 100. Contributions to the Biology of the Philippine Archipelago and Adjacent Regions. Volume 2, part 5. The Shipworms of the Philippine Islands. By Paul Bartsch. Volume 6, part 2. Additions to the Polychaetous Annelids collected by the United States Fisheries steamer *Albatross*, 1907–1910, including one new genus and three new species. By A. L. Treadwell. Volume 6, part 3. Report on the Hydroida collected by the United States Fisheries steamer *Albatross* in the Philippine Region, 1907–1910. By Charles C. Nutting.

Bulletin 134. Material Culture of the People of Southeastern Panama, based on specimens in the United States National Museum. By Herbert W. Krieger.

Bulletin 135. Life Histories of North American Marsh Birds. Orders Odontoglossae, Herodiones, and Paludicolae. By Arthur Cleveland Bent.

Bulletin 136. Handbook of the Collection of Musical Instruments in the United States National Museum. By Frances Densmore.

Bulletin 137. The Collection of Primitive Weapons and Armor of the Philippine Islands in the United States National Museum. By Herbert W. Krieger.

Bulletin 138. The Fossil Stalk-Eyed Crustacea of the Pacific Slope of North America. By Mary J. Rathbun.

Bulletin 139. Fire as an Agent in Human Culture. By Walter Hough.

Bulletin 140. Bird Parasites of the Nematode Suborders Strongylata, Ascaridata, and Spirurata. By Eloise B. Cram.

Of the separate papers of the Contributions from the United States National Herbarium the following were issued:

Volume 22, part 10. The North American Species of Scutellaria. By Emery C. Leonard.

Volume 23, part 5. Trees and Shrubs of Mexico. (Bignoniaceae-Asteraceae.) By Paul C. Standley.

Volume 24, part 8. The Grasses of Ecuador, Peru, and Bolivia. By A. S. Hitchcock.

Volume 26, part 1. The Lecythidaceae of Central America. By H. Pittier.

Volume 26, part 2. The Piperaceae of Panama. By William Trelease.

Of the separates from the proceedings, 20 were from volume 69, 23 from volume 70, and 12 from volume 71.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY

The editorial work of the bureau has continued under the direction of the editor, Mr. Stanley Searles.

During the year two bulletins and one special publication were issued.

Bulletin 82. Archeological Observations North of the Rio Colorado, by Neil M. Judd. 171 pp., 61 pls., 46 figs.

Bulletin 83. Burials of the Algonquian, Siouan and Caddoan Tribes West of the Mississippi, by David I. Bushnell, jr. 103 pp., 37 pls., 3 figs.

List of publications of the Bureau of American Ethnology.

Publications in press or in preparation are as follows:

Forty-first Annual Report. Accompanying papers: Coiled Basketry in British Columbia and Surrounding Region (Boas, assisted by Haeberlin, Roberts, and Teit); Two Prehistoric Villages in Middle Tennessee (Myer).

Forty-second Annual Report. Accompanying papers: Social Organization and Social Usages of the Indians of the Creek Confederacy; Religious Beliefs and Medical Practices of the Creek Indians; Aboriginal Culture of the Southeast (Swanton); Indian Trails of the Southeast (Myer).

Forty-third Annual Report. Accompanying papers: The Osage Tribe; Two Versions of the Child-naming Rite (La Flesche); Wawenock Myth Texts from Maine (Speck); Native Tribes and Dialects of Connecticut (Speck); Picuris Children's Stories, with Texts and Songs (Harrington); Iroquoian Cosmology.—Part II (Hewitt).

Forty-fourth Annual Report. Accompanying papers: Excavation of the Burton Mound at Santa Barbara, California (Harrington); Social and Religious Usages of the Chickasaw Indians (Swanton); Uses of Plants by the Chippewa Indians (Densmore); Archeological Investigations—II (Fowke).

Bulletin 84. A Vocabulary of the Kiowa Language (Harrington).

Bulletin 85. Contributions to Fox Ethnology (Michelson).

Bulletin 86. Chippewa Customs (Densmore).

REPORT OF THE AMERICAN HISTORICAL ASSOCIATION

The annual reports of the American Historical Association are transmitted by the association to the secretary of the Smithsonian Institution and are communicated by him to Congress as provided by the act of incorporation of the association.

The annual report for 1921, part 1 of the annual report for 1922, and the supplemental volume to the report for 1923 were issued during the year. Part 2 of the annual report for 1922 and the supplemental volume to the report for 1924 were in press at the close of the year.

REPORT OF THE NATIONAL SOCIETY, DAUGHTERS OF THE AMERICAN REVOLUTION

The manuscript of the Twenty-ninth Annual Report of the National Society, Daughters of the American Revolution, was transmitted to Congress, in accordance with the law, January 8, 1927.

SMITHSONIAN ADVISORY COMMITTEE ON PRINTING AND PUBLICATION

The editor has continued to serve as secretary of the Smithsonian advisory committee on printing and publication, to which are referred for consideration and recommendation all manuscripts offered to the Institution and its branches. Five meetings were held during the year and 83 manuscripts acted upon.

Respectfully submitted.

W. P. TRUE, *Editor.*

DR. C. G. ABBOT,
Acting Secretary, Smithsonian Institution.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDED JUNE 30, 1927

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds, receipts, and disbursements of the Institution and a statement of the appropriations by Congress for the following Government bureaus in the administrative charge of the Smithsonian Institution: The National Museum, the International Exchanges, the Bureau of American Ethnology, the National Zoological Park, the Astrophysical Observatory, the International Catalogue of Scientific Literature, and the National Gallery of Art; also for an additional assistant secretary and for printing and binding for the fiscal year ended June 30, 1927.

SMITHSONIAN INSTITUTION

Condition of the endowment fund July 1, 1927

The sum of $1,000,000 deposited in the Treasury of the United States under act of Congress is part of a permanent endowment fund, which includes the original Smithson fund and additions accumulated by the deposit of savings and bequests from time to time. Subsequent bequests and gifts and the income therefrom, when so required, are invested in approved securities. The several specific funds so invested are now constituted and classed as follows:

Consolidated fund

Avery fund	$40, 456. 46
Virginia Purdy Bacon fund	62, 272. 93
Lucy H. Baird fund	1, 728. 09
Chamberlain fund	35, 000. 00
Hamilton fund	500. 00
Caroline Henry fund	1, 223. 33
Hodgkins general fund	37, 275. 00
Bruce Hughes fund	14, 158. 90
Lucy T. and George W. Poore fund	21, 296. 42
Addison T. Reid fund	7, 299. 16
Rhees fund	357. 34
Roebling fund	150, 000. 00
George H. Sanford fund	675. 72
Smithson fund	1, 516. 40
Total consolidated fund	373, 759. 75
Charles D. and Mary Vaux Walcott research fund	11, 520. 00

The total amount of dividends and interest, etc., received by the Institution from the Freer estate during the year for all purposes was $249,737.84 and the amount received from sale of Freer estate stocks and bonds was $1,152,735.58.

The itemized report of the auditor, the Capital Audit Co., certified public accountants, is filed in the office of the secretary.

DETAILED SURVEY OF FINANCIAL OPERATIONS

Parent fund

Balance on hand or in time deposits July 1, 1926		$7,451.41
Receipts:		
Income consisting of interest and receipts from miscellaneous sources available for general purposes	$59,444.97	
International exchanges, repayments to the Institution	5,947.24	
Total receipts		65,392.21
Total resources for general purposes		72,843.62
General expenditures:		
Care and repair of buildings	7,761.54	
Furniture and fixtures	583.06	
General administration	24,356.37	
Library	4,124.83	
Publications (comprising preparation, printing, and distribution)	14,166.78	
Researches and explorations	1,743.19	
International exchanges	4,782.92	
Total general expenditures		57,518.69
Balance June 30, 1927		15,324.93

Funds for specific objects, including payment and return of funds advanced for field expenses and other temporary transactions during the year

Balance on hand or in time deposits July 1, 1926		$71,340.53
Receipts:		
Abbott, Haiti and Santo Domingo expedition fund	$1,007.50	
American Silurian Crinoids Vol. fund, Springer	1,592.28	
Avery fund	4,719.93	
Virginia Purdy Bacon fund	7,145.90	
Lucy H. Baird fund	168.34	
Laura Welsh Casey fund	4,000.00	
Frances Lea Chamberlain fund	4,748.98	
Colombian botanical exploration fund	2,826.96	
Endowment campaign expense fund	16,013.50	
Endowment fund, general	134.00	
Frick vertebrate paleontological exploration fund	500.00	
Hamilton fund	203.40	
Harriman Trust fund	12,700.00	
Caroline Henry fund	130.76	

Receipts—Continued.

Hodgkins fund, specific	$7,493.02	
Bruce Hughes fund	1,486.65	
Morris Loeb fund	1,401.87	
Catherine Walden Myer fund	3,750.28	
North American Wild Flowers publication fund	50,488.80	
Paleontological researches	604.87	
Cornelia Livingston Pell fund	2,000.00	
Lucy T. and George W. Poore fund	3,729.42	
Addison T. Reid fund	1,437.65	
Rhees fund	73.65	
John A. Roebling, Roebling fund	151,562.50	
John A. Roebling, mineral collection fund	4,530.00	
John A. Roebling, solar research, etc., funds	3,409.12	
George H. Sanford fund	138.02	
Homer E. Sargent, Salish manuscript fund	299.50	
Charles T. Simpson fund	1,500.00	
Smithsonian Chrysler expedition	20,219.96	
Springer fund	2,355.00	
Swales fund	1,013.00	
Charles D. and Mary Vaux Walcott fund	955.00	
Charles D. and Mary Vaux Walcott fund reserve for investment	15.00	
Refund of temporary advances, etc	6,622.89	
Total receipts		$320,977.75
Total resources		392,318.28

Expenditures:

Abbott, Haiti and Santo Domingo expedition fund, expended	500.00	
American Silurian Crinoids Vol. fund, Springer, expended	3,592.28	
Avery fund, invested and expended	2,565.59	
Virginia Purdy Bacon fund, expended	2,926.80	
Lucy H. Baird fund, invested	200.00	
Laura Welsh Casey fund, expended	2,595.40	
Chamberlain fund, expended	5,114.49	
Colombian botanical exploration fund, expended	2,826.96	
Frederick G. Cottrell fund, expended	2,000.00	
Endowment campaign expense fund, expended	19,701.08	
Hamilton fund, expended	38.00	
Harriman Trust fund, for researches, etc., expended	12,132.10	
Hodgkins fund, specific for researches, expended	6,284.23	
Morris Loeb fund, expended	4,037.76	
North American wild flowers publication fund, expended	51,572.21	
Osage fund, expended	23.44	
Paleontological researches, expended	1,645.00	
Cornelia Livingston Pell fund, expended	978.08	
Lucy T. and George W. Poore fund, invested	2,760.00	
John A. Roebling, Roebling fund, invested and expended	150,950.00	
John A. Roebling, mineral collection fund, expended	4,435.20	
John A. Roebling, solar research, etc., expended	6,772.76	

Expenditures—Continued.		
W. A. Roebling mineral fund, expended	$644.19	
Charles T. Simpson fund, expended	337.41	
Smithsonian-Chrysler expedition, expended	9,403.17	
Springer fund, expended, etc	1,615.00	
Swales fund, expended	1,381.09	
Charles D. and Mary Vaux Walcott fund, expended	639.30	
Temporary advances for field expenses, etc	7,549.36	
Total expenditures		$305,226.90
Balance June 30, 1927		87,097.38

Charles L. Freer bequest

Balance on hand or in time deposits, July 1, 1926		56,097.46
Receipts:		
Dividends, interest, and miscellaneous receipts	$249,737.84	
Sale of stocks and bonds, etc	1,152,735.58	
Total receipts		1,402,473.42
Total resources		1,458,570.88
Expenditures:		
Operating expenses of gallery, salaries, purchase of art objects, field expenses, and incidentals	180,851.12	
Investments in sinking fund, etc	49,985.25	
Reinvestment of funds from sale, etc., of stocks and bonds	1,127,329.33	
Total expenditures		1,358,165.70
Balance June 30, 1927		100,405.18

SUMMARY

Total balances of all funds, July 1, 1926		134,889.40
Receipts during year ending June 30, 1927:		
Parent fund, for general expenses		65,392.21
Revenue and principal of funds for specific objects except Freer bequest		320,977.75
Freer bequest		1,402,473.42
Total		1,923,732.78
Expenditures:		
General expenses of the Institution	$57,518.69	
Specific objects except Freer bequest	305,220.90	
Freer bequest	1,358,165.70	
Total expenditures		1,720,905.29
Total balances of all funds, June 30, 1927		202,827.49
Total		1,923,732.78

All payments are made by check, signed by the Secretary of the Institution, on the Treasurer of the United States, and all revenues are deposited to the credit of the same account. In some instances

deposits are placed in bank for convenience of collection and later are withdrawn in round amounts and deposited in the Treasury.

The practice of investing temporarily idle funds in time deposits has proven satisfactory. During the year the interest derived from this source, together with other similar items, has resulted in a total of $3,813.38.

The following appropriations for the Government bureaus in administrative charge of the Smithsonian Institution were made by Congress for the fiscal year 1927:

Bureau:		Appropriation
International Exchanges		$46, 260
American Ethnology		57, 160
International Catalogue of Scientific Literature		7, 500
Astrophysical Observatory		31, 180
Additional Assistant Secretary		6, 000
National Museum—		
Furniture and fixtures	$23, 730	
Heating and lighting	78, 140	
Preservation of collections	450, 000	
Building repairs	12, 000	
Books	1, 500	
Postage	450	
		565, 820
National Gallery of Art		29, 381
National Zoological Park		173, 199
Printing and binding		90, 000
Total		1, 006, 500

Respectfully submitted.

Frederic A. Delano,
R. Walton Moore,
Executive Committee

PROCEEDINGS OF BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION FOR THE FISCAL YEAR ENDED JUNE 30, 1927

ANNUAL MEETING, DECEMBER 9, 1926

Present: The Hon. William H. Taft, Chief Justice of the United States, chancellor; The Hon. Charles G. Dawes, Vice President of the United States; Senator Reed Smoot; Senator George Wharton Pepper; Senator Woodbridge N. Ferris; Representative Albert Johnson; Representative R. Walton Moore; Representative Walter H. Newton; Mr. Charles F. Choate, jr.; Hon. Henry White; Mr. Robert S. Brookings; Hon. Irwin B. Laughlin; Mr. Frederic A. Delano; Mr. Dwight W. Morrow; and the secretary, Dr. Charles D. Walcott.

Dr. Charles G. Abbot and Dr. Alexander Wetmore, Assistant Secretaries of the Institution, were present by invitation.

PRESENTATION OF BUST OF ALEXANDER GRAHAM BELL

Mr. Walter S. Gifford, president of the American Telephone & Telegraph Co., in presenting to the Institution a bust of Alexander Graham Bell, on behalf of the company, delivered an impressive brief address outlining the relations of Professor Bell to the Smithsonian and to the telephone. He described an incident illustrating the encouragement Bell had received at a critical time in his career from Joseph Henry, first Secretary of the Smithsonian Institution, and concluded his address as follows:

Alexander Graham Bell was grateful to Joseph Henry for that encouragement all his life. No less, I am sure, was he grateful to this Institution. So, too, with us, the scientific sons and heirs of Alexander Graham Bell, with our reverence for the memory of Joseph Henry and our appreciation of this noble center of science and culture, I assure you, gentlemen, that as we come here to-day there is in our feeling something of gratitude for that vital encouragement from the great Secretary of the Smithsonian to the young inventor of the telephone just at the time when he needed that encouragement most.

Mr. Chancellor, gentlemen of the Board of Regents of the Smithsonian Institution, and Mr. Secretary, in behalf of the American Telephone & Telegraph Co., and in commemoration of the fiftieth anniversary of the birth of the telephone, I present to you this bust of Alexander Graham Bell.

Mrs. Gilbert H. Grosvenor, daughter of Doctor Bell, then unveiled the bust, which was accepted by the chancellor, who said:

Mr. President, on behalf of the Board of Regents, I beg to express their grateful appreciation of this gift, so appropriate and, I may say, so appropriately presented.

We are indebted to Professor Bell's daughter for coming here to unveil this bust, a bust of strength and force, and an excellent sculptural representation.

Professor Bell's relation to the Smithsonian Institution has been close, through all of our recollections, and it seems most fitting that we should have this speaking likeness under our custody where we can exhibit it as a memorial of one of the great benefactors of the human race.

The secretary then introduced the sculptor, Mr. Victor Salvatore, thus closing the ceremony, after which the regular order of business was taken up.

APPOINTMENT OF REGENTS

The secretary announced that on December 19, 1925, the Speaker of the House of Representatives had reappointed Messrs. Albert Johnson, of Washington; R. Walton Moore, of Virginia; and Walter H. Newton, of Minnesota, as House Regents.

Also that the President had approved joint resolutions appointing the following as citizen Regents for six years:

From January 7, 1926; Mr. Dwight W. Morrow, of New Jersey;

From March 20, 1926: Mr. Charles F. Choate, jr., of Massachusetts.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE

The annual report of the executive committee for the fiscal year ending June 30, 1926, was accepted by the board.

ANNUAL REPORT OF THE SECRETARY

The secretary, in presenting his annual report for the fiscal year ending June 30, 1926, said that 109 publications had been issued since the last annual meeting of the Regents. Of these, 44 were published by the Institution proper, 63 by the National Museum, and 2 by the Bureau of American Ethnology. There were distributed during the past fiscal year 168,932 copies of these publications.

ANNUAL REPORT OF THE PERMANENT COMMITTEE

The report of the permanent committee outlined briefly the status of important current matters, including the solar radiation researches, the Smithsonian-Chrysler Expedition, the Canfield collection of minerals, the Roebling collection of minerals, the Myer bequest, the consolidated fund, the Freer sinking fund, the Smithsonian scientific series, and the increase of endowment project. In accepting the committee's report, the board adopted resolutions of thanks to Mr. Walter P. Chrysler, to the family of the late Frederick A. Canfield, and to Mr. John A. Roebling for their generous gifts to the Institution.

ANNUAL REPORT OF THE NATIONAL GALLERY OF ART COMMISSION

The secretary then submitted the annual report of the National Gallery of Art Commission, the contents of which will be printed in the report of the Secretary of the Smithsonian for the fiscal year ending June 30, 1927.

On motion the board accepted the report and adopted the following resolutions:

Resolved, That the Board of Regents hereby approves the recommendation of the National Gallery of Art Commission that Gari Melchers, Herbert Adams, and Charles Moore be reelected as members of the commission for the ensuing term of four years, their present terms having expired.

Resolved, That the board also approves the recommendation of the commission that Clarence Zantzinger, architect, of Philadelphia, be elected a member of the commission to fill the vacancy caused by the declination of John Russell Pope, and that, in the event of Mr. Zantzinger's declination, the vacancy be filled by the election of Charles Borie, architect, of Philadelphia.

THE DOGNIN COLLECTION OF MOTHS AND BUTTERFLIES

The secretary reported that the National Museum had acquired the Dognin collection of moths and butterflies, consisting of more than 82,000 specimens, including not less than 3,000 types of American species described by Dognin and about 250 types, almost entirely American, of other describers. These, added to the 5,000 types personally described by Doctor Schaus, make the National Museum's collection in this line unrivaled.

Mr. White offered the following resolutions, which were adopted:

Resolved, That the thanks of the Board of Regents of the Smithsonian Institution are hereby conveyed to the contributors to a fund of some $50,000 for the purchase of the Paul Dognin collection of moths and butterflies.

Resolved, That the thanks of the board are also tendered Dr. William Schaus, honorary assistant curator of the division of insects of the National Museum, for his initiative and personal efforts in securing the contributions that have made possible the acquisition of this large and valuable addition to the collections of the Museum.

RESOLUTION RELATIVE TO INCOME AND EXPENDITURES

Mr. Delano, on behalf of the executive committee, offered the following resolution, which was accepted:

Resolved, That the income of the Institution for the fiscal year ending June 30, 1928, be appropriated for the service of the Institution, to be expended by the secretary with the advice of the executive committee, with full discretion on the part of the secretary as to items.

SPECIAL COMMITTEE ON POLICY OF THE INSTITUTION

The secretary stated that with the development of the Institution it had become desirable to have appointed a special committee to consider its future, and submitted the following resolution, which was adopted:

Resolved, That a committee is hereby created, consisting of the members of the executive committee and two other members of the board, to be designated by the chancellor, to consider the future course of the development of the Institution and to submit its recommendations to the board at its next meeting.

The chancellor thereupon appointed as the members of this special committee Messrs. Choate, Delano, Moore, Morrow, and White.

REGULAR MEETING, FEBRUARY 10, 1927

Present: The Hon. William Howard Taft, Chief Justice of the United States, chancellor; the Hon. Charles G. Dawes, Vice President of the United States; Senator Reed Smoot; Senator George Wharton Pepper; Senator Woodbridge N. Ferris; Representative Albert Johnson; Representative R. Walton Moore; Representative Walter H. Newton; Mr. Frederic A. Delano; Hon. Irwin B. Laughlin; Mr. Dwight W. Morrow; and the acting secretary, Dr. Charles G. Abbot.

DEATH OF SECRETARY WALCOTT

The chancellor feelingly announced the death of the secretary, and after remarks, appointed Senator Pepper, Mr. Delano, and Mr. Moore as a committee on resolutions.

The committee submitted the following resolutions which on motion were adopted:

The Board of Regents of the Smithsonian Institution have received the intelligence of the death, on February 9, 1927, of Charles Doolittle Walcott, Secretary of the Institution since 1907. It is thereupon

Resolved, That the board record both their sense of personal bereavement and their keen realization of the loss sustained in the death of their distinguished secretary, whose geological researches and varied scientific attainments have brought him eminence in the world of scholarship, and whose administration as the executive officer of the Institution has made it more than ever a predominant force in scientific thought and achievement, and enlarged its influence for the attainment of the founder's purpose—" the increase and diffusion of knowledge among men."

Resolved, That the executive committee be requested to arrange for a memorial meeting to be held in Washington and for the submission at such meeting of a suitable record of the life and work of Doctor Walcott.

Resolved, That a copy of these resolutions be transmitted by the chancellor to Doctor Walcott's family, with an expression of the sense of the heavy loss sustained by the Institution, and of the sympathy of the Regents with the family in this the hour of their bereavement.

APPOINTMENT OF REGENTS

The acting secretary announced that the Vice President had made the following appointments of Regents, effective March 4, 1927:

Senator Reed Smoot, to succeed himself.

Senator Joseph T. Robinson, to succeed Senator George Wharton Pepper.

ENDOWMENT MEETING

The acting secretary stated that in deference to the wish of the late Secretary Walcott, expressed a few days before his death, and seconded by the wish of Mrs. Walcott, the conference on the future of the Smithsonian would be held on February 11, as planned. A very interesting exhibit had been installed, calculated to show some of the researches which the Institution is uniquely qualified to undertake if sufficient financial means become available. The President of the United States and a notable group of eminent men had accepted the invitation of the board to attend. Addresses would be given by the chancellor and the acting secretary, in which the relations of the Institution to the Government, and its many-sided functions in the promotion of research and publication would be set forth.

WHAT IS THE "SMITHSONIAN"?

The acting secretary recalled to the board that the Smithsonian Institution is a private foundation, the ward of the United States, engaged in many types of activities, international in scope and catholic in its attention to science; that under its initiative nine bureaus of the Government had developed, of which seven are still administered by the Institution as one type of its many activities. For these bureaus approximately a million dollars annually are appropriated by Congress. These appropriations have been increased in recent years, so that while in 1922 the sum appropriated for them was $765,120, the present bill for the fiscal year 1928 carries $1,132,711.

Yet these increasingly liberal governmental appropriations go not to support the Smithsonian Institution, but domestic bureaus under its administration which are indispensable to the public, and which Congress supports because of public demand. Advantages to both the Government and the Institution arise from Smithsonian administration of them. The only disadvantage arises from the fact that owing to its immense domestic service, the public has come to regard the Smithsonian as a Government bureau, supported by public funds. Thus it has not received the additional endowment which its general needs require.

The Institution itself ought to receive a sufficient endowment to enable it to deal broadly with fundamental research and publication irrespective of obvious utilities; to grasp opportunities when they arise; to employ experts as needed; to pension superannuated employees and to increase its force and its scale of compensation. Its present condition is one of chronic penury. Endowment funds, not

annual grants, are needed for the purpose described, because annual grants are uncertain, inclastic to meet opportunities as they arise, and rigidly restricted in expenditure in ways fatal to research needs.

FREER INHERITANCE TAX

Mr. Delano made a statement in connection with the attempts to procure a refund of tax of $475,000 upon the Freer estate. After discussion, the following resolution was adopted:

Resolved: That the matter of the refund of money paid by the Freer executors to the State of Michigan as an inheritance tax be referred to Mr. Delano, with the request that he visit Detroit and make an investigation into all the circumstances, with the view to a possible appeal to the Michigan Legislature by the Board of Regents for the refund of the amount in question.

HACHENBERG WILL

The acting secretary informed the board that the Institution had been left, under the will of Dr. George P. Hachenberg, of Austin, Tex., a half interest in his farm, subject to a life estate of his daughter and her son. The attorney in Texas who had been consulted recommended that the property be held for future disposition.

No formal action was taken.

SMITHSONIAN SCIENTIFIC SERIES

The acting secretary reported that, pursuant to authorization, a contract had been entered into with the Smithsonian Series Corporation by which the Institution agreed to prepare manuscripts and illustrations for a series of 20 books of interesting character to be printed and sold by subscription by the said corporation.

REPORT OF SPECIAL COMMITTEE

Mr. Delano, on behalf of Mr. Henry White, chairman, submitted a report of the special committee on the future policy of the Institution, recommending that certain important matters be deferred for consideration at a later meeting.

On motion the report was received, and after discussion it was decided that the proposed meeting of the board should be held on a date to be selected by the acting secretary.

ACTING SECRETARY

At the suggestion of the chancellor, the following resolution was adopted:

Resolved: That the Assistant Secretary of the Smithsonian Institution, Dr. Charles Greeley Abbot, is hereby designated as acting secretary, and pending future action of the board is authorized to perform the duties of the Secretary of the Institution.

SPECIAL MEETING, MARCH 14, 1927

Present: The Hon. William Howard Taft, Chief Justice of the United States, chancellor; Senator Reed Smoot; Senator Joseph T. Robinson; Representative R. Walton Moore; Representative Walter E. Newton; Mr. Frederic A. Delano; Hon. Irwin B. Laughlin; Mr. Dwight W. Morrow; and Dr. Charles G. Abbot, acting secretary.

Dr. Alexander Wetmore, assistant secretary, was present by invitation.

THE CHARLES D. WALCOTT BEQUEST

The acting secretary read extracts from the will of the late secretary making certain conditional bequests to the Institution. Formal action was deferred.

ROEBLING GIFT

The acting secretary reported that, as authorized by the board, he had executed on its behalf the deed of gift formally conveying to the Institution the Roebling collection of minerals and an endowment of $150,000 for its maintenance.

ZOO BIRD HOUSE

After statements by Doctor Abbot and Doctor Wetmore, a resolution was adopted providing that the acting secretary, or secretary, with the advice and consent of the executive committee, should represent the board in all matters pertaining to the contracts and construction of the proposed bird house at the National Zoological Park, and authorized that it be carried forward up to the limit of the existing appropriation, with a view to applying later to Congress for the sum necessary to complete the building as projected.

RESEARCH AND PUBLICATION

The acting secretary then gave a statement of the research work and publication now under way or planned.

EXECUTIVE SESSION

Doctor Abbot and Doctor Wetmore retired at this point, and the board went into executive session for the purpose of considering the report submitted by the special committee.

GENERAL APPENDIX

TO THE

SMITHSONIAN REPORT FOR 1927

ADVERTISEMENT

The object of the General Appendix to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution from a very early date to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and, during the greater part of its history, this purpose has been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880, induced in part by the discontinuance of an annual summary of progress which for 30 years previously had been issued by well-known private publishing firms, the secretary had a series of abstracts prepared by competent collaborators, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1927.

ACCOMPLISHMENTS OF MODERN ASTRONOMY

By C. G. Abbot

[With 11 plates]

It is natural to ask such questions as the following:

1. How many stars are there and how are they arranged?

2. How far away are the stars and how large?

3. What do we know of the constitution, age, and source of energy of heavenly bodies, and what relations hold regarding their temperatures and the rays they constantly emit?

4. Whither and how fast are the heavenly bodies moving?

5. What is the bearing of astronomical discovery on the province of life?

There are many other interesting astronomical questions, but a vivid impression of the greatness of the accomplishments of recent years will come from a survey of these five alone.

1. NUMBER OF STARS AND THEIR ARRANGEMENT

It was long ago suggested that if the stars are infinite in number, and if space is infinite in extension, the whole vault of the heavens should glow as brightly as the sun. The interposition of absorbing matter would not alter this conclusion, because, according to Kirchhoff's law, the whole interior of a space with walls of constant temperature takes up the temperature of the walls. Hence absorbing matter surrounded by an infinite army of stars would at length be as hot as they.

Obviously, therefore, the stars are not infinitely numerous and they occupy little volume relative to the space in which they lie. In order to estimate the numbers of stars, a careful study of the numbers brighter than certain magnitudes has been made. First of all, however, the scale of brightness required to be standardized. Very anciently, some of the brighter stars were called of first magnitude, others less bright, such as the Pole star, of second magnitude, and so on. It was found that the values assigned by these ancient estimates could be nearly duplicated by assuming that an increase of five magnitudes produces exactly 100-fold decrease in apparent brightness, and that the logarithm of the change of brightness for one magnitude is

$$\frac{\log. 100}{5} = 0.4000$$

With this exact definition of what had formerly been a rough and ready classification, several observers have attained great distinction by their long-continued researches in stellar photometry, which means the assignment of exact magnitudes to the stars. Some of these investigators made visual observations at the telescope, but, as in other lines in astronomy, photography was employed by others with great advantage. The ordinary photographic plate is most sensitive to blue and violet light, while the eye is most sensitive to light-green and yellow. Hence, while some observers were contented to measure photographic brightness by ordinary plates, others interposed absorbing screens suitable to restrict the rays to the most effective visible region, and observed on orthochromatic plates.

Thus the values of brightness of the stars have been measured not only photographically but photovisually, as we may say, and the magnitudes have been recorded on both scales. Reddish stars are naturally much fainter according to photographic than according to visual or photovisual magnitudes. The difference of the two scales gives, indeed, a measure of the effective colors of stars, which, in cases of objects too faint for spectroscopic analysis, is valuable as an index of the character of the spectrum.

By persevering work along these lines, there have been established in recent times standard series of stars of fainter and fainter apparent luminosity, so that the observer in any part of the heavens, by making comparison photographs from time to time within standardized stellar regions, may reduce his observed magnitudes to a well-settled standard scale, no matter what the prevailing sky conditions for the night may be.

With these advantages it has become possible to count accurately the numbers of stars brighter than specified magnitudes, as photographed within selected areas, each of small but definite extent, and numerous enough to give a fair estimate of the star population of the whole heavens. In the following table, prepared by Seares and van Rhijn, we see how the numbers run.

TABLE I.—*Numbers of stars brighter than a given magnitude*

Magnitude limit	Number of stars		Ratio visual	Magnitude limit	Number of stars		Ratio visual
	Photographic	Visual			Photographic	Visual	
4	360	530		12	1,100,000	2,270,000	2.6
5	1,030	1,620	3.1	13	2,720,000	5,700,000	2.5
6	2,940	4,850	3.0	14	6,500,000	13,800,000	2.4
7	8,200	14,300	3.0	15	15,000,000	32,000,000	2.3
8	22,800	41,000	2.9	16	33,000,000	71,000,000	2.2
9	62,000	117,000	2.9	17	70,000,000	150,000,000	2.1
10	166,000	324,000	2.8	18	143,000,000	296,000,000	2.0
11	431,000	870,000	2.7	19	275,000,000	560,000,000	1.9

Thus the total numbers of stars brighter than a given magnitude increase nearly by ratios of 3.0-fold as we pass from step to step, until we come down to stars of magnitude 9, which are some fifty times fainter than the naked eye can see. Then the ratio of increase grows steadily smaller until at the nineteenth magnitude the ratio has diminished to 1.9. The relation of this ratio of increase to the magnitude number may be expressed by a suitable formula.

With this mathematical expression it is easily possible to proceed beyond the twentieth magnitude to integrate the probable numbers of stars, on the assumption that this formula, which holds so well down to the faintest telescopic magnitudes, still continues to retain its validity beyond. *In this way Seares has computed that our galaxy of stars probably contains about 30,000,000,000 stars, or some twenty times as many stars as there are living human inhabitants of the earth.*

Looking in the direction of the constellations of Cassiopeia, Aquila, Sagittarius, and Crux, we see the hazy brightness of the milky way, which, when examined with a telescope, resolves itself into a multitude of stars. The milky way is easily seen to be a nearly flat ring, extending completely around the heavens, and is frequently taken as the datum plane from which to chart star positions. Thus astronomers speak of galactic latitude and longitude.

If the average number of stars per square degree brighter than a given magnitude are classified with reference to their galactic latitudes, it is immediately seen that toward the galactic poles they are few compared to the numbers near or in the galaxy itself. In the following table (after Seares and van Rhijn) this information is collected:

TABLE 2.—*Galactic concentration of the stars*

NUMBERS OF STARS PER SQUARE DEGREE BRIGHTER THAN A GIVEN PHOTOGRAPHIC MAGNITUDE

Limiting magnitude	Galactic latitude			
	0°	20°	40°	90°
	Number	*Number*	*Number*	*Number*
7	0.36	0.22	0.14	0.10
11	20.8	11.6	7.3	4.3
15	910	400	199	87
19	20,750	6,860	2,180	770

Naked-eye stars are three times as concentrated in the milky way as at its poles. But for very faint stars the ratio of concentration is thirtyfold.

How shall we explain this inequality of distribution of the stars and more especially of faint ones? Either their ranks extend much

farther along the plane of the milky way than toward its poles, or else a pair of veils of progressively increasing obscurity, like two caps, one on either side of the galaxy, hide from us the multitude of stars which otherwise might be seen toward the galactic poles. The second hypothesis is too fantastic. *Astronomers agree, therefore, that our system of some 30,000,000,000 stars is contained in a lens-shaped space some five times as extended in diameter along the galactic plane as at right angles thereto.*

2. DISTANCES AND DIAMETERS OF STARS

When Copernicus conceived the sun to be the center of the earth's orbit, and the apparent motions of the stars to be merely the consequences of the earth's daily axial rotation, he required of his disciples for the next three centuries a great faith. For they must believe that the stars are all so distant that the immense circuit of the earth about the sun neither seemed to bring any stars nearer, nor even caused them to appear to approach and recede, one from another, as trees do when we pass a forest. It was not until about the year 1840 that the most refined measurements disclosed any angular displacements of stars attending the annual revolution of the earth. Then three star distances were measured by Bessel, Henderson, and Struve, respectively, and found to be between twenty and seventy trillion miles.

At the beginning of the twentieth century less than 100 star distances were known. About that time a new method was introduced, in which photography was substituted for eye observation at the telescope. By dimming a bright star in the center of the telescopic field, so as to compare equally with very faint stars about it, we may obtain at six-month intervals properly exposed photographs. Since the very faint stars will almost always be faint because of immense distances, the photographic image of the artificially dimmed star, probably much nearer, will often be found to wander very slightly to and fro among neighboring star images in the six-month intervals, owing to the earth's annual revolution. By assiduous and careful investigations of this kind, which have been carried on at several observatories, these paralactic angular displacements have been determined for nearly 2,000 stars in the past 25 years. Even with the utmost accuracy, however, it is impossible to do more than show that a star is relatively a distant one, if it lies beyond the distance requiring of light 500 years to traverse.

As comparatively few of the stars lie within 500 light years' distance from the earth, we should be little satisfied unless there were other methods of extending our knowledge of star distances. As concerning measurements of the distances of individual stars, there

are two principal methods adapted to stretch the limit of measurement considerably further. The first depends on the existence of numerous pairs of stars in mutual revolution about their common centers of gravity.

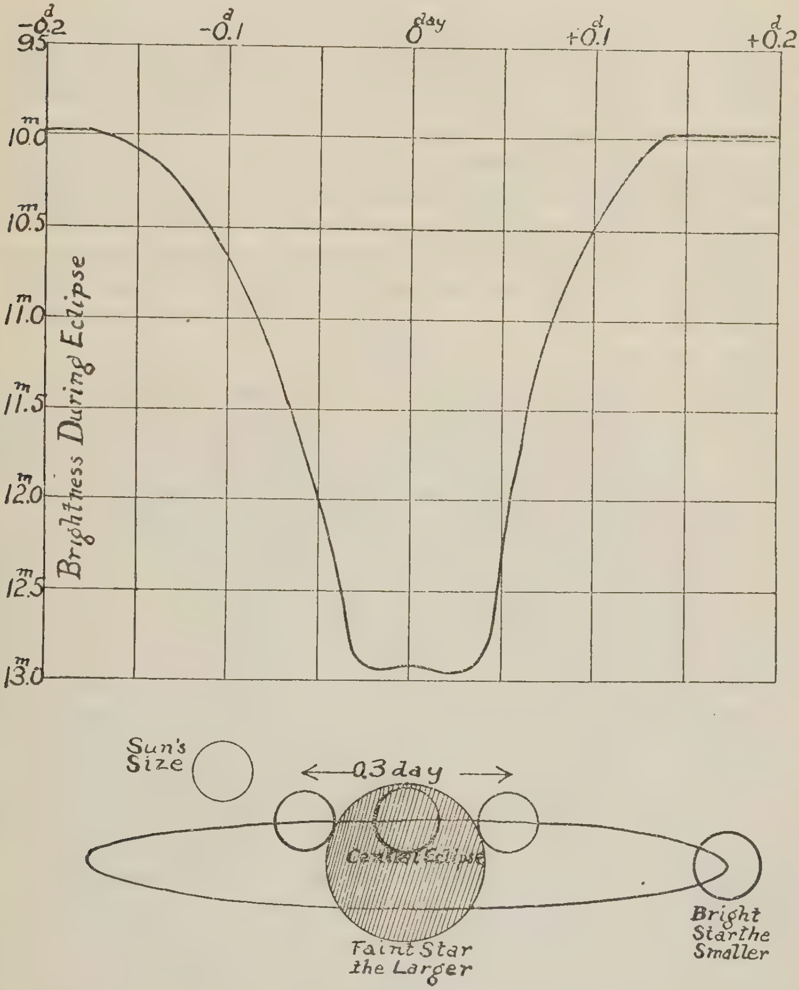


FIG. 1.—Curve of light variation of a star which is periodically eclipsed by a larger dark body, as seen from the earth

Although too near together to be distinguished as double by the telescope, the duplicity of stars is sometimes recognized by the regularly recurring variation of their light, owing to their mutually eclipsing one another. In many other cases the spectroscope detects duplicity by the periodic shifting of the spectral lines, as the stars tend alternately to approach and recede from the earth in their

orbits. However, it is not of such close double stars as the eclipsing and the spectroscopic binaries that distances are determined, but of the numerous pairs of stars seen telescopically separate, and observed sufficiently long to trace a considerable part of their apparent orbits in the heavens.

In such cases the law of Kepler, which is a consequence of Newton's law, informs us: $M_1+M_2=A^3/P^2$ where M_1 and M_2 are the masses of the two stars compared to the earth plus the sun, A, the semiaxis of their orbit in terms of the semiaxis of the earth's orbit, and P the period of rotation measured in years. If M_1+M_2 were known, A could be computed. Fortunately the study of eclipsing and spectroscopic binaries has proved that for most double stars the combined masses differ little from double the mass of the earth and sun. Hence it is assumed in this method of obtaining star distances that $M_1+M_2=2$.

If so $A=\sqrt[3]{2P^2}$

Inasmuch as the factor of the combined mass enters in the cube root, the result would be only 100 per cent in error if M_1+M_2 were really 16 instead of 2, so that measurements of A, made in this manner, are generally of comparatively high accuracy. Since the angular measure of A is readily observed with the telescope, the star's distance from the earth corresponding to the linear measure found by the application of Kepler's law follows immediately. Nearly 1,000 stellar distances have been determined by this, the so-called "dynamical" method.

A still more fruitful means of measuring star distances depends on a close scrutiny of certain absorption lines in their photographic spectra. In the latter years of the nineteenth century the spectra of the stars were arranged at the Harvard College Observatory in certain great classes called B, A, F, G, K, M, ranging from the blue stars of type B, through the solar stars of type G, to the red, or Antarian stars of type M. Certain gradations of these great classes are recognized, such as B5, meaning a type half way between the most extreme, or B0 stars, and the most extreme varieties of type A, called A0.

It is found, however, that two stars both of the type G5, for instance, though generally identical in spectrum, may show a few of their characteristic spectral lines in very different intensities. These minute spectral differences have been shown, from both observational and theoretical standpoints, to be due to differences in size of the stars. If two such stars were at equal distances, so as to display their absolute magnitudes, or true luminosities, the one of larger diameter would, of course, be the brighter. The distances of a great many stars have been so well determined by the trigonometric and dynamical methods that it has become possible to fix a scale of appear-

ance of these telltale spectral lines, such that, knowing their appearance in a given star, its absolute brightness is immediately assigned. Knowing, also, its apparent brightness from photometric observations, the distance follows at once. In this way the distances of nearly 3,000 individual stars have been measured spectroscopically.

Omitting in this hasty sketch distances determined by several special methods of limited application, we come finally to the wholesale methods depending on apparent brightness and on apparent angular motion. It is sufficiently obvious that if all stars were of identical spectrum and luminosity, their brightness would vary inversely as the square of their distance. By making allowance for spectrum, and assuming that large and small stars are mixed in the same proportions in the distant parts of the universe that they are in those relatively near, formulae have been devised which give the average relative distances of stars of the successive stellar magnitudes. It is also obvious that on the average of great numbers the apparent angular motion of stars, or so-called "proper motion," must be inversely as their distances. This wholesale method of estimating stellar distances in terms of proper motions has been extensively applied, and appropriate formulae have been devised to express it.

These wholesale formulae are checked by the known individual distances of several thousand stars. *They enable us to treat statistically such majestic problems as the absolute size of our stellar system, which we call our galaxy. It is estimated to be approximately 100,000 light years in its maximum and 20,000 light years in its minimum diameter. Its 20 nearest stars are from 4 to 15 light years distant from us.*

Knowing the distances of several thousand stars individually, it has been found that our sun is near the middle rank in absolute brightness, although, to us, it seems brighter than Sirius. Yet, in fact, Rigel is about ten thousand times brighter than the sun, and the sun about ten thousand times brighter than the faintest stars yet known.

As for the sun, its diameter has long been known to be 860,000 miles. Only recently have the diameters of some other stars been determined. This has been done in some cases by direct measurements with the interferometer according to the method of Michelson, but only for a few stars, including Betelgeuse, Antares, Arcturus, Aldebaran, and some others. *The gigantic red stars first named are found to be from 200,000,000 to 400,000,000 miles in diameter, or several hundred times that of the sun.* On the other extreme, several bright stars, including Sirius, are found less than twice the diameter of the sun. If it were possible to carry the measurements to very faint stars, doubtless some would be found much smaller than the

sun. Several indirect methods, depending on the distribution and intensity of light in the spectra of the stars, enable us to estimate the diameters of some of the very faint stars, and this confirms our expectation of their relatively minor size. One yellowish white star, indeed, appears to be no larger than our earth.

3. DENSITIES AND TEMPERATURES OF STARS—THEIR INTERNAL STRUCTURE

Since there have been found no stars of masses many times greater than that of the sun, but a whole class of gigantic red stars several hundred times the sun's diameter, and therefore millions of times the sun's volume, *it follows that the density of these red giants is of an order a thousand times less than atmospheric air.* The study of eclipsing variables, many of which are blue and white stars, has also indicated a range of densities, not, indeed, so excessively rare. but still of the order a thousand times less than the sun's.

As there are many stars of the greatest similarity in size and spectrum to the sun, we must believe that these approximate the solar density, which is one and four-tenths times that of water. Yet this is by no means the maximum limit of density, for the companion to the brilliant star Sirius has lately been proved to be some sixty thousand times as dense as water, or three thousand times as dense as platinum! To add to the astonishment which this statement evokes, this star, like all others, is mainly gaseous, and is even in that state of great freedom of internal motion called perfectly gaseous.

At ordinary temperatures gases may be compressed in the laboratory far beyond the density of water, but their molecules then occupy such large volumes compared to the spaces between that the internal motions of highly compressed gases are hindered, and they are no longer perfect gases. But at the immense temperatures which prevail within the stars not only are the molecules disassociated but their atoms also are ionized, so that in place of the relatively bulky molecules the separated electrons and nuclei only remain. These primitive particles are so excessively small that stars may be compressed far beyond the densities of our heaviest solid substances without losing their perfectly gaseous qualities.

Thus the interiors of the stars are in the simplest possible condition for theoretical studies. Eddington and others have taken full advantage of this favorable condition and have worked out so thoroughly the relation of pressure, temperature, diameter, energy, and constitution, and with such excellent accordance with what can be astronomically observed among the host of heavenly bodies, that we may be said to know far more of the internal condition of the stars than we do of the interior of the earth.

It appears that starting with the red giants at less than 3,000° absolute C. of surface temperature, the successive classes K, G, F, A, and B exhibit a scale of constantly rising surface temperatures, culminating with approximately 16,000° absolute C. for the surface of such a star as Rigel. Our own sun, at 6,000° absolute C., is medium in this as in other characters.

Within the stars two forces strive against the enormous compressive force of gravitation. These are, first, the agitation of the electrons, and atomic nuclei, after the fashion of pressures in all gases, and second, the pressure of radiation. In the interior of stars, the temperatures, which may reach 40,000,000°, are so exalted that the radiation therein exerts perfectly tremendous pressure. At such temperatures the prevailing wave lengths are of the order of X rays, rather than of visible light. Such very short wave rays are unable to penetrate more than a few centimeters through the ionized atomic gas of the stellar substance. Under these circumstances the energy of the interior is imprisoned, and after reaching the blue stage the central parts of a star grow hotter and hotter; they are, though, quite unable to prevent the exterior from cooling back through the successive spectrum classes A, F, G, K, and M, with constantly increasing density. Hence we find two kinds of red and yellow stars, one sort very bulky and rare, the other relatively very small and dense. Our sun belongs to the dwarf class, having passed the acme of brightness.

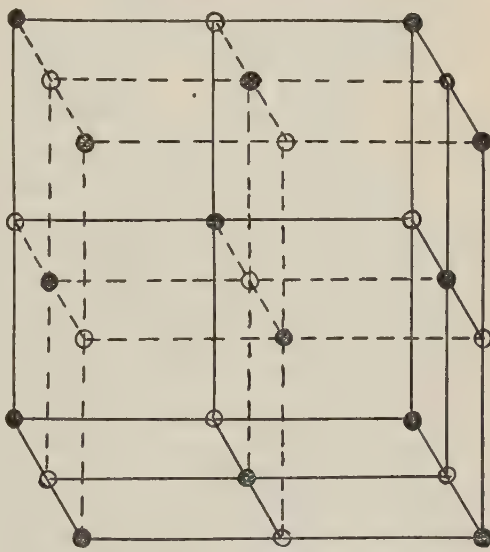


FIG. 2.—The arrangement of atoms as it is in common salt, whose molecules each contain one atom of chlorine and one of sodium. Each of these atoms in its turn is made up of a family of electric charges, positive and negative in equal numbers. The running together of these charges annihilates the atoms, and gives up energy to maintain the radiation of sun and stars

Until recent years the source of energy which maintains the tremendous outward flow of stellar radiation was unexplained. Now, however, the atoms are shown to consist entirely of groups of equal electric charges, positive and negative, supposed to remain separate by virtue of orbital motion. *It is conceived that under the cir-*

cumstances of exalted temperature and pressure prevailing within stars, union of these electric particles may occur, with annihilation of mass and liberation of energy. If so, a source adequate to supply stellar energy for immense periods of time is available.

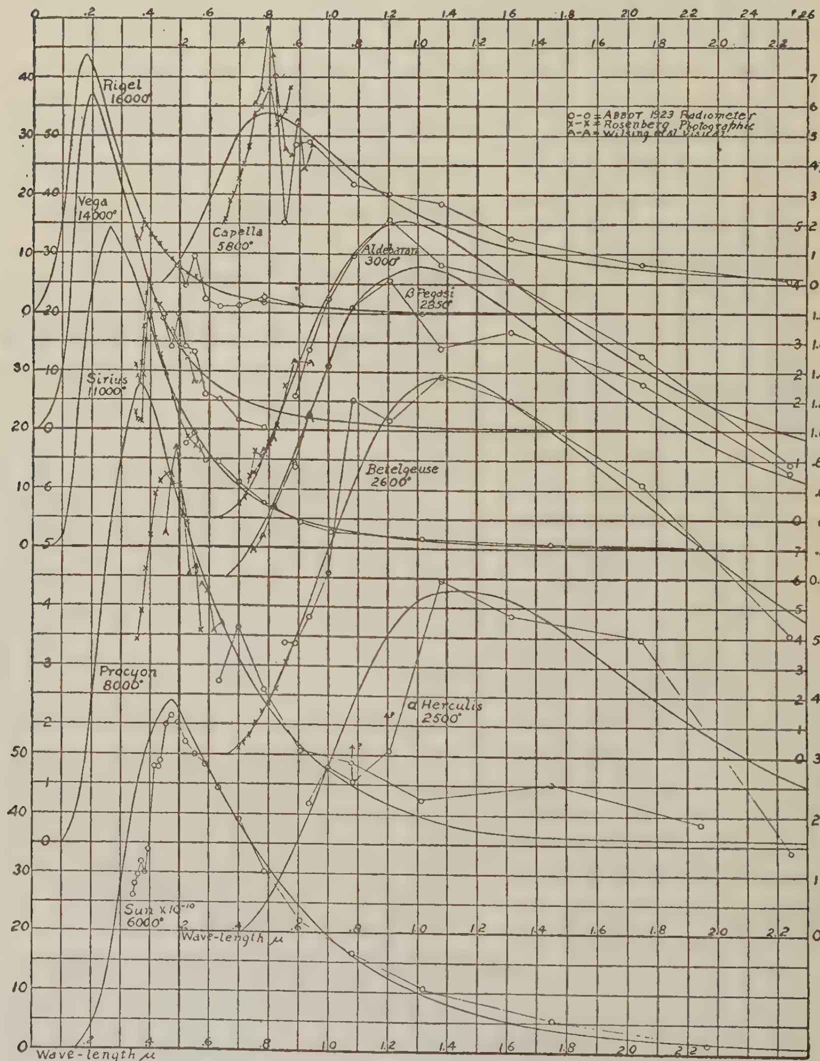


FIG. 3.—The temperatures of the stars estimated by comparing their spectral-energy curves with those of the perfect radiator

From the known mass of the sun it is computed that if it were completely annihilated with evolution of energy, the supply would suffice to maintain the present rate of solar radiation about fifteen trillion years. So the present view ascribes enormous ages to the stars, abundantly sufficient to satisfy the most extravagant time

demands which biologists and geologists may be led to make from their studies of existing life and the paleontological records of the past.

The surface temperatures of the stars are estimated by measuring the distribution of the energy of their radiation in the spectrum. As the blacksmith's iron glows with a different color according to the degree of its heat, so do the stars. Laboratory experiments have developed laws and formulae, connecting the temperatures and energy spectra of sources, which, like the stars, emit continuous spectra. It is by applying these relations that star temperatures are determined.

The surface temperatures of the hotter stars exceed any which we are able to maintain continuously in the laboratory. Hence it is very useful that Anderson has recently invented a method of exploding wires by tremendous electric discharges, able to yield instantaneous temperatures of 20,000° to 30,000°. This permits the experimental study of radiation from such hot sources.

It was a mystery until recently why the profusion of intense Fraunhofer lines which exist in the spectra of yellow stars, like our sun, should yield to fainter and fewer lines for still hotter stars. Indeed, in the blue stars of Type B0 the visible and photographic spectra are almost devoid of lines. We now understand that the absence of lines does not mean the absence of the chemical elements which produce them. Rather the elementary atoms, under the tremendous excitations prevailing in these very hot star surfaces, have lost several of the electrons of their outer orbits. They are "stripped," as physicists say, and the residual fragments of such stripped atoms give spectra whose lines are beyond the short-wave limit of spectra transmissible by our atmosphere.

If it were not for a high-level layer of atmospheric ozone, so scanty that if brought to the earth's surface it would make a gaseous mantle no thicker than a sheet of cardboard, the sun and stars would send us rays of much shorter wave lengths. In these extreme ultraviolet regions would be found the rich line spectra of the stripped atoms of the hotter stars.

All that we know of astronomy depends on radiation. But the nature of radiation itself is more mysterious than was supposed 30 years ago. At the end of the nineteenth century it was agreed that radiation is a transverse wave vibration, set up in the luminiferous ether by the stimulus of the violent internal motions of the molecules of heated substances. All of the phenomena of the propagation of light, highly complex and varied though they are, seemed to be explained satisfactorily in this way. Yet now the newly gained

knowledge of the composition and interior structure of the atoms, including the phenomena of radioactivity, seems to require a reconsideration of the older hypothesis of corpuscular radiation, which Newton preferred. In short the emission and the absorption of rays seems to demand a discontinuous corpuscular explanation, while the propagation of rays no less imperiously demands the acceptance of the vehicle of continuous wave-motion. These antagonistic views now await reconciliation.

4. MOTIONS OF THE STARS

The observations of such men as Bradley of Oxford, the great Astronomer Royal, and all of his successors who have measured accurately the positions of the stars, form a precious heritage. They have rendered their makers' names immortal. For it is by comparing these early star positions with the corresponding ones of to-day, that a knowledge of the angular displacements, called proper motions of the stars, is determined. All the stars, including our sun, are on the move. The most rapid star moves over 10 seconds of arc per year. Now that stellar distances, as well as proper motions, have become known, these angular displacements are easily converted into linear velocities, though of course seen in projection on the celestial sphere.

Within the past 30 years another element of stellar motion has been added, for the spectroscope has determined for us the rates of approach or recession of several thousand stars. This, too, is but partial knowledge, for it gives only the component of a star's true motion, relative to the earth, which is projected upon a radius of the celestial sphere. Yet when the proper motions and the radial motions of the stars are combined, as they can now be, we obtain the true motions of the stars in space, relative to the earth, or if we prefer, to the sun. *The sun moves about 12 miles per second, and other star velocities range from 5 to 100 miles per second.*

A large number of true space motions were computed a few years ago by Strömberg, with the result of revealing *a great common highway, along which not only the various groups of stars of different spectral types, but the great star clusters, and even the spiral nebulæ, seemed to be moving with reference to our sun.* The phenomenon has been compared by Adams to the flights of a number of swarms of bees, which, fortuitously, had chosen a common path for their migrations. Individual swarms would fly at unequal rates, and individual bees at cross directions to the common course, so that a wide dispersion of swarms and individuals would appear. Yet on the whole the common course would predominate.

In order to understand this majestic march of the celestial hosts, we must first review the recent studies by Hubble of the spiral nebulæ and their relation to our galaxy of stars. Hubble has been able, in photographs by the 100-inch reflector, to resolve several spiral nebulæ, including the Great Nebula of Andromeda, into hosts of separate stars of excessive faintness. Some of these stars he finds

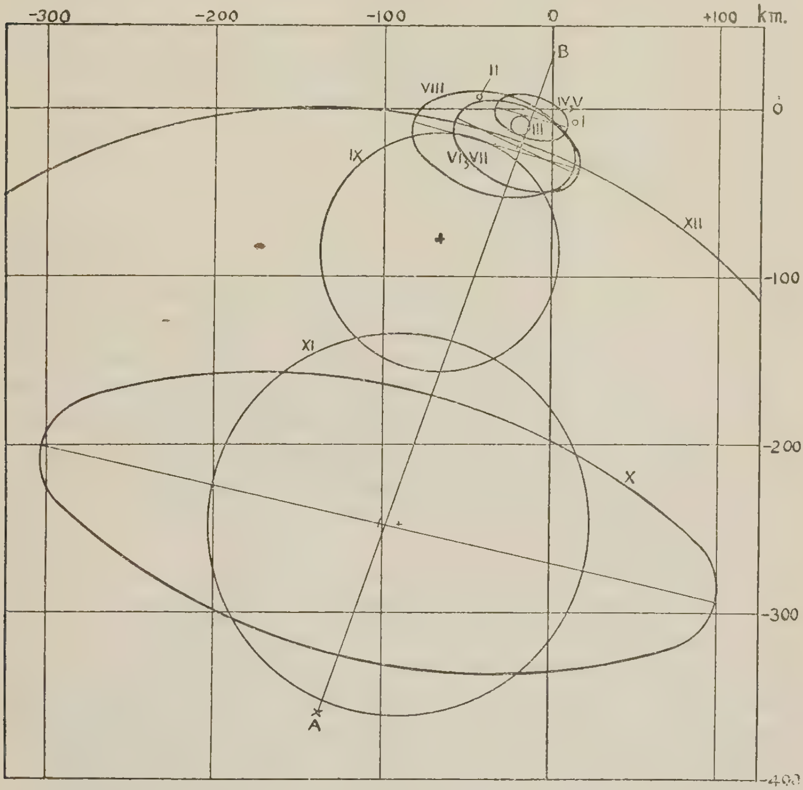


FIG. 4.—The march of stars as compared to the place of the sun. If all the groups, I to XII, of the stars were collected at the sun, at the intersection of the lines 0 0, then after a certain time the several groups would all seem to have moved along the general direction B A, and to have spread out to fill the figures shown. This great celestial way lies nearly toward the star Antares

to be of the Cepheid type of variable brightness. Shapley had shown that these variables are standard objects whose periods of variation are truly indicative of their absolute brightness. Hence Hubble was able to determine, from the periods of variation, the real brightness of these Cepheids found within the spiral nebulæ. This done, their distances followed at once, from a knowledge of their apparent magnitudes.

He found the distance of the Great Nebula of Andromeda to be about 900,000 light years, and some of the other spirals to be some nearer, some more distant. Thus these objects lie quite outside the limits of our galaxy of stars. They are, as Herschel suggested, island universes. Their shapes, as photographed in some cases on edge, suggest the configuration of our galaxy. Their sizes, in some instances at least, are not dissimilar to it.

Hence we are led to suppose that our own galaxy is a rather more than usually large and mature spiral nebula, in which almost all the nebulous matter has been agglomerated into stars. Its age is so great that the stars of different masses and different ages have taken on very unequal rates of motion.

Originally, as we may suppose, our own nebula, like all others, traveled in a certain direction with respect to the general algebraic zero of motion of all spiral nebulæ, at the rate of several hundred kilometers per second. This direction happened to be what we observe now as the great common star way. Our own star, the sun, happens to be moving nearly along the great common way, and as its motion exceeds the average rate of some star groups, it is imparting to them an apparent negative velocity. A still higher apparent negative velocity equal to the real velocity of our own system is imparted in the same manner to the algebraic zero of motion of the other spiral nebulæ. Such is an explanation of the grand parade of the celestial hosts.

5. SOME ASPECTS OF ASTRONOMY AND LIFE

We have been dealing hitherto with gigantic things. Billions of stars, millions of degrees of temperatures, sextillions of miles of distance, trillions of years of time, the march of the celestial hosts—all these tremendous facts have been on review before us. Is it not, then, the height of anticlimax to turn away, at the ending, to consider the affairs of the solar system, ruled by that middling star, our sun, and comprising no other objects which could so much as be discerned by any intelligent dwellers among the nearest of the other stars?

It can not appear so to one who is familiar with the intricacies of the chemistry and the physics, the marvels of the instincts and the adaptations and the triumphs of the infinitesimal, by which, for instance, the characters of a mature man are controlled by the constitution of the two microscopic germ cells which united to create him. These occur only in life, and life, so far as we yet positively know, occurs only in the solar system. It is not therefore so much the academic astronomy of the sun and planets, as their relations to life, which now I wish to touch upon in closing.

Although life on other planets than the earth is not positively demonstrated, there are two others, Mars and Venus, on which its existence is not out of the question. Yet life depends upon a nice adjustment of various conditions. There is no chemical element except carbon which combines with other elements in that infinite variety of potent forms so indispensable to the mysterious processes of life. Flexibility, too, is requisite, so that liquids rather than solids must have a considerable part in living creatures. Of all liquids water is the most important, but even of the numerous organic carbon-built liquids, those more conducive to life properties solidify as water does at about zero centigrade. These considerations incline us to think that planetary temperatures about as high as the earth's are requisite at least to the higher forms of life.

It has recently been observed that the illuminated side of Mars reaches equatorial temperatures approximating those of our spring days in Philadelphia. Both oxygen and water vapor have been demonstrated in the atmosphere of Mars, but in comparatively minute quantities. Adams and St. John find of oxygen 15 and of water vapor 5 per cent of the quantities prevailing in our atmosphere. *So the Martian life, if it exists, must be adapted to atmospheric composition approximating that high above the summit of Mount Everest.*

As the atmosphere of Mars is so very rare and dry, it is unsuitable to retain heat at night. Computation and observation unite in estimating the midnight temperatures of equatorial Mars as of the order of $-40°$ C. These frigid night temperatures, combined with the rare and dry atmosphere, would seem to exclude from Mars the higher types of life, such as we know, but might permit certain arctic types to exist. Indeed, the seasonal changes of color which are observed, seem to many to be satisfactory evidence of vegetation on Mars.

Upon Venus there is no defect of temperature, or of the uniformity of it. With greater nearness to the sun but higher reflecting power, the solar radiation available to warm Venus is about one and four-tenths times as intense as that which warms the earth. Accordingly, temperatures approximating those of our Tropics should prevail in latitudes well toward this planet's poles. An abundant atmosphere is present. The reflecting power approximates that of a completely cloudy earth, so that it would be reasonable to conceive of clouds of water, completely hiding the planet surface at all times.

The spectroscope, however, does not confirm this. Neither water-vapor nor oxygen can certainly be discerned thereby. Yet it seems incredible that we see the surface of this planet, whose bulk must be solidified since its density is nearly the same as the earth's. For if

solid, surely it would present some visible markings, and Venus never does. Accordingly, it is supposed that the clouds of Venus are of the high-level cirrus type, and that water-vapor, though present plentifully below the clouds, is too scanty at higher levels to be revealed. As for oxygen, though certainly it can not extend as high as it does above the earth, it may be present beneath the cloud level.

No spectroscopic evidence of the rotation of Venus has ever been found. This proves that the planet does not rotate very rapidly, like the earth or Mars. It has even been suggested that, like the moon, its rotation and revolution periods are identical so that Venus would present the same face to the sun at all times. If that were so, the bright face would be very hot, and the dark face very cold. Recently, however, Pettit and Nicholson have found that the dark side of Venus is about equally warm from one edge to the other and is everywhere at about the same temperature that our earth would appear if viewed from another planet. This observation of moderate and equable night temperatures proves that the planetary rotation must be fairly rapid, and certainly not of the same period as the revolution. *We may therefore conclude that Venus is very probably appropriately provided with temperature, humidity and atmospheric conditions, and is in a state suited for luxuriant life. Being wholly cloudy, however, it is doubtful if we can ever demonstrate it.*

The earth, therefore, still remains the only known abode of life, and her life depends absolutely on the sun's radiation. Recent studies have shown that this dependence rests on very narrow margins of safety. For instance, the oxygen of the upper atmosphere is induced to combine into the form of ozone by the influence of extreme ultra-violet solar rays, and yet the ozone formed is continually being reconverted into oxygen by the influence of still other extreme ultra-violet solar rays. Thus occurs a balance of these effects such that the upper atmosphere contains so minute a quantity of ozone as would make, if brought to earth, a gaseous layer only as thick as a cardboard. Yet this minute and almost fortuitous atmospheric constituent cuts off entirely the spectrum of the sun and stars beyond wave length 2,900 Angstroms. The solar rays thus cut off, if they reached the earth, would destroy human sight and tissues by their powerful chemical activity. Of course, we could shield ourselves from these effects, but our ancestors who lived before the invention of spectacles would have lost their sight, or never attained it. Yet if the atmospheric ozone absorption reached only a little further, to 3,200 Angstroms, human and animal young would languish with the enfeebling disease of rickets, for the extreme ultra-violet rays are indispensable to proper mammalian growth.

As ozone absorbs to some extent even as far as 3,200 Angstroms, a catastrophe might ensue if circumstances led to a small increase of the ozone content of our atmosphere. For this would eliminate indispensable rays of wave lengths 2,900 to 3,200 Angstroms. Such a catastrophe would attend such an alteration in the distribution of the extreme ultra-violet solar spectrum as would change materially the existing balance of influences tending to produce and destroy ozone.

This leads us to inquire if the sun is a constant star, and, if not, what is the character of its variation. The fluctuations of sun spots and other visible solar phenomena which have long been known, prove, of course, that the sun is not absolutely constant. Within the last 22 years the Smithsonian Institution has made some thousands of determinations of the intensity of solar heating, which prove that the solar radiation increases several per cent at times of maximum visible solar activity. Apparently, too, the sun's surface presents appreciable inequalities of radiating power, so that the rotation of the sun leads to successive brief changes of the intensity received at the earth's surface. These changes are slight for red and infra-red rays, but grow more and more considerable for the shorter wave lengths. Pettit, indeed, observing with the narrow band of ultra-violet rays which silver transmits, centering at 3,160 Angstroms, finds alterations of over 100 per cent in their intensity. This means that if our eyes were sensitive to such rays alone we should find the sun's surface twice as bright at some times as at others.

Other solar phenomena exhibit interesting variations. Nearly 20 years ago Hale discovered magnetism in sun spots, and later over the sun's whole surface. Sun spots are apt to go in pairs, and Hale finds that if the advancing spot of a pair is a north pole in the northern solar hemisphere, it will be a south pole which leads in a spot pair in the southern hemisphere. But this state of things endures only through one 11-year sun-spot cycle. In the following cycle these polarities reverse, so that 22⅓ years are required to bring back the magnetic conditions to the starting point. Bjerknes has proposed an ingenious hypothesis to account for sun spots, their coolness, their going in pairs, the opposite magnetic polarity of the pair, and the reversal of polarity at each 11-year cycle. It depends on hydrodynamic principles and explains the phenomena as due to causes residing within the sun, not to gravitational influences of the planets.

It is well known that terrestrial magnetism reacts to solar activity, and so does the aurora as well. Bauer has shown that the earth's magnetic state marches closely with the intensity of solar radiation as measured by the Smithsonian Institution. Very recently Austin

has found that the reception of long-range radio signals also marches hand in hand with the intensity of solar radiation.

The weather, too, so important to human concerns, seems to be affected by solar changes. The importance of this effect is still in controversy, so that I shall not stress it, but merely remark that time will tell. However, I must point out that the solar variation, though obviously associated with the 11-year sun-spot cycle, has hitherto seemed irregular, and therefore unpredictable. But now there seem to appear definite periodicities of 25⅔, 15, and 11 months, and certain harmonics of these periods, which, together with the 11-year period, seem to make up the whole long-interval solar variation. If these definite periodicities should persist, we shall be in position to forecast for years in advance the principal solar variation and everything which may be found to depend upon it.

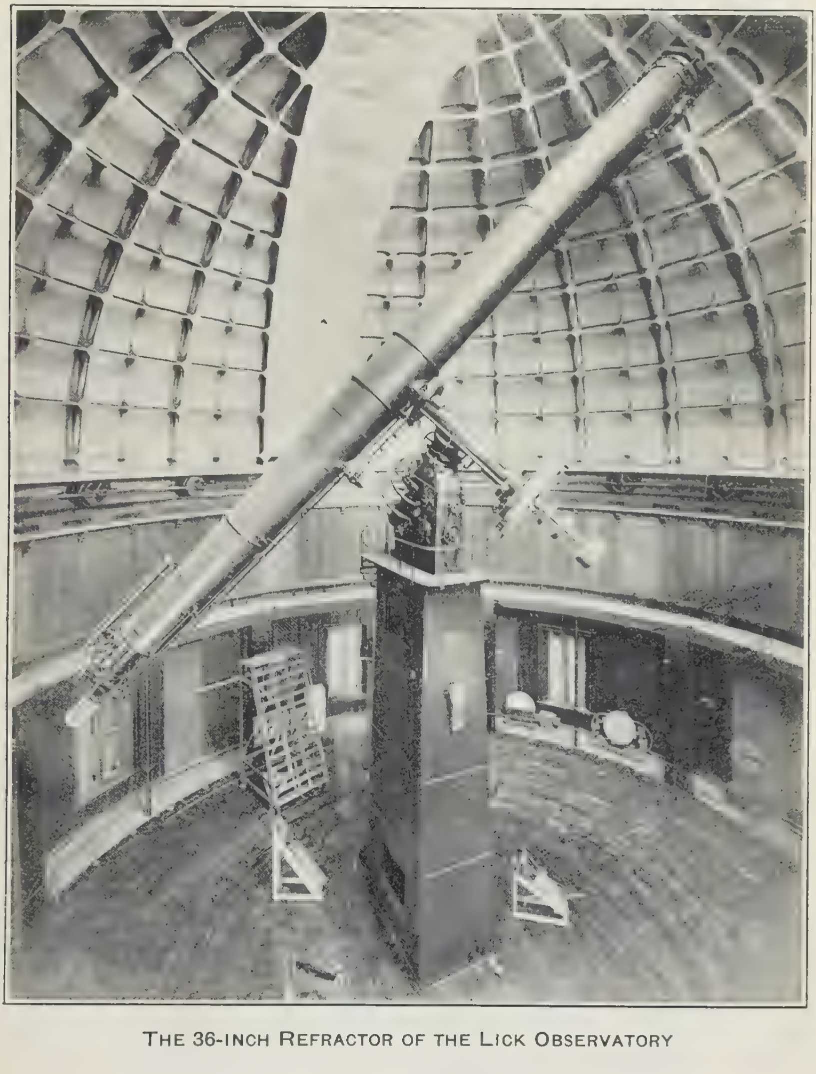
I should give but a feeble impression of the importance of sunlight to life if I should stop at this point. All plants grow by absorbing solar energy and using it to promote chemical reactions in a way still inimitable by chemists. Ultra-violet rays, too, produce certain changes of chemical structure in fats and oils which are the source of those traces of hormones so extraordinarily important, all out of proportion to their infinitesimal occurrence, in the growth and health of animals. The more searching study of the solar spectrum in its relations to these extraordinary chemical reactions is a most fascinating field.

On the grosser side the application of solar energy to power production also offers an attractive research field. Some are disposed to think this chimerical. There are, however, certain lines of improvement over former attempts at the utilization of solar rays directly for power which, I am inclined to think, will solve the problem commercially.

Thus far we have mentioned only points of contact between astronomical research and physical life. Yet this aspect, interesting as it is, should yield place to appreciation of the value of astronomy to broaden the mental outlook, to vanquish fear, and to allay superstition. While yet the vast numbers and masses of the stars were unknown, their nature unrecognized, the existence of other galaxies undreamed of, men very naturally regarded the earth as the central object and themselves the beings for whom all things were created. Now the universe has attained such grandeur that earth sinks to the dimensions of a speck, and we can not but accept an attitude of wholesome humility. At the same time, the consciousness of having achieved already so great a command of the forces of nature, and so considerable a knowledge of her mysteries, and the assurance that we can soon command and know far more, tempers humility with elation.

A SKY-REGION OF MANY STARS, NEAR δ NORMAE

The dark lanes and patches show regions where the fainter stars are hidden by dark nebulosity intervening between us and them

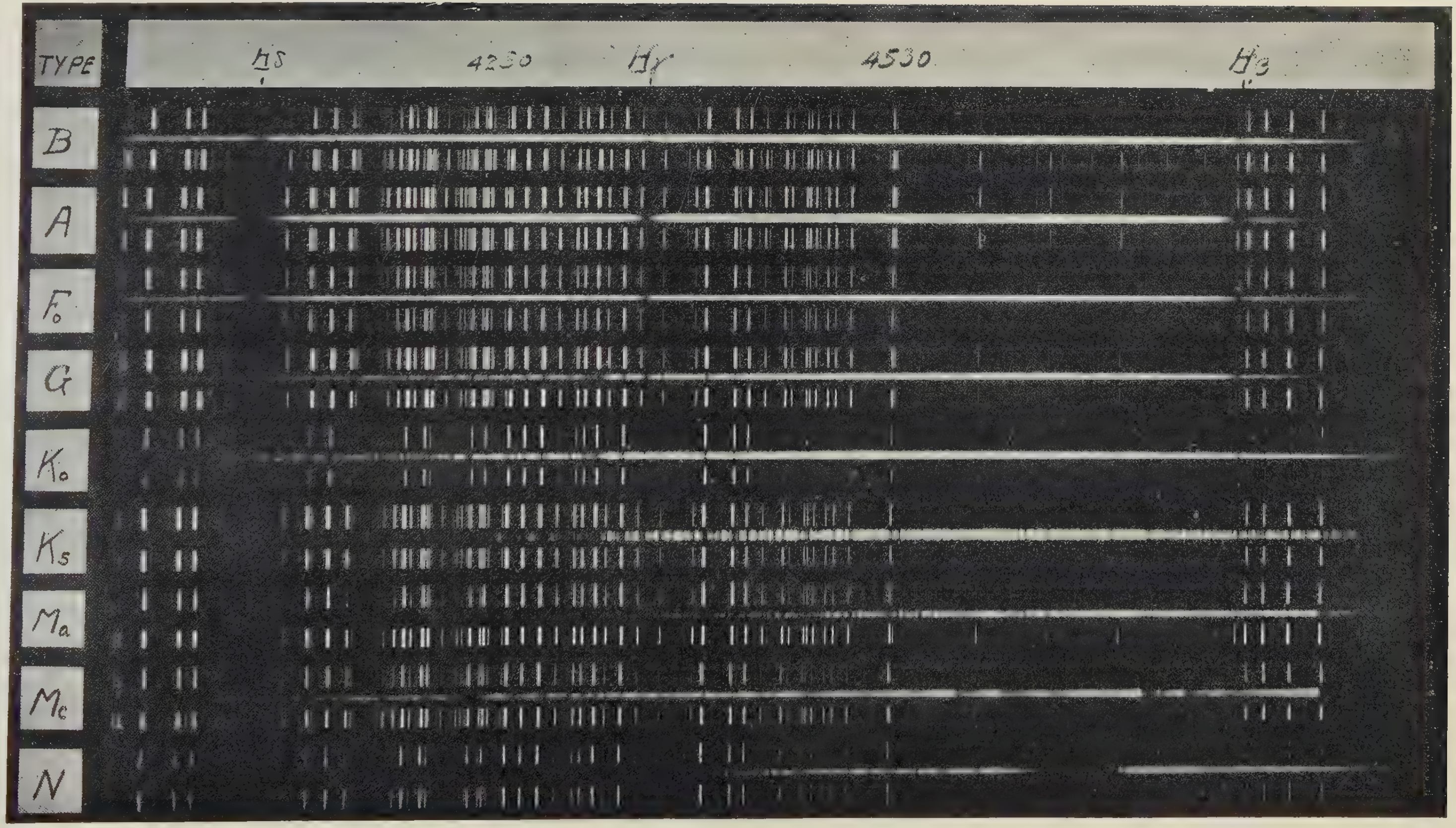


THE 36-INCH REFRACTOR OF THE LICK OBSERVATORY

TOTAL SOLAR ECLIPSE, MAY, 1900. THE PLANET MERCURY AT THE EXTREME RIGHT

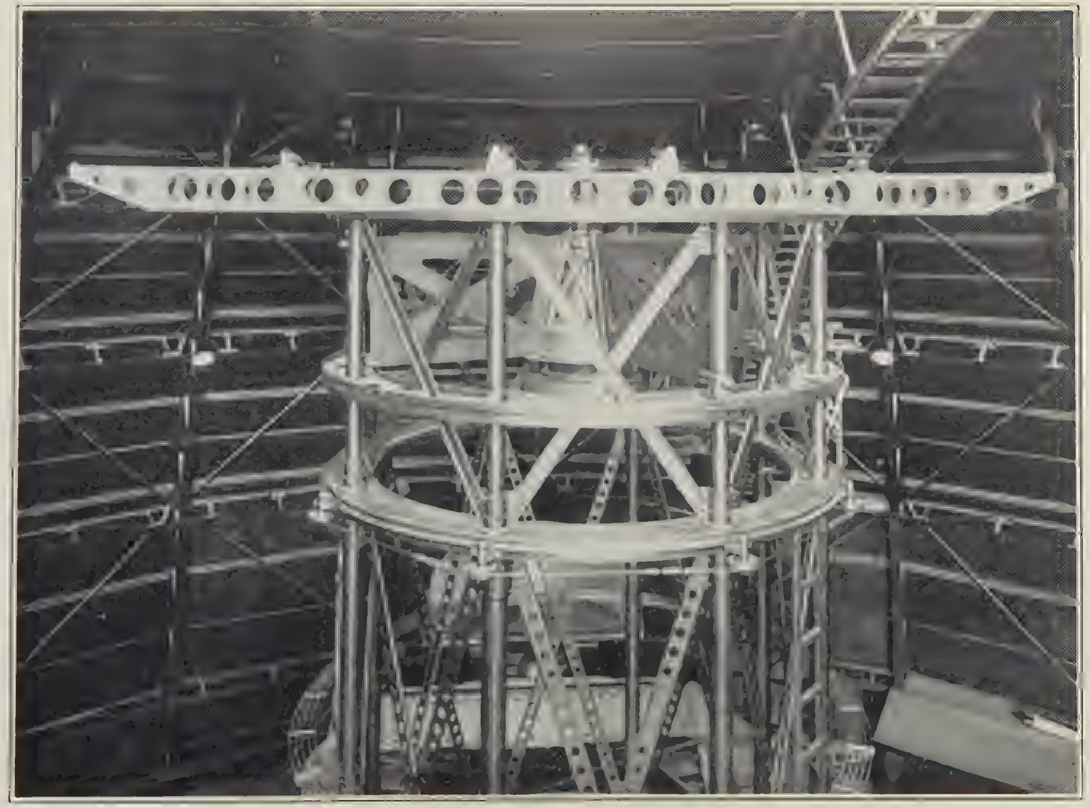
(Photograph by Smillie, Smithsonian)

SIR ISAAC NEWTON



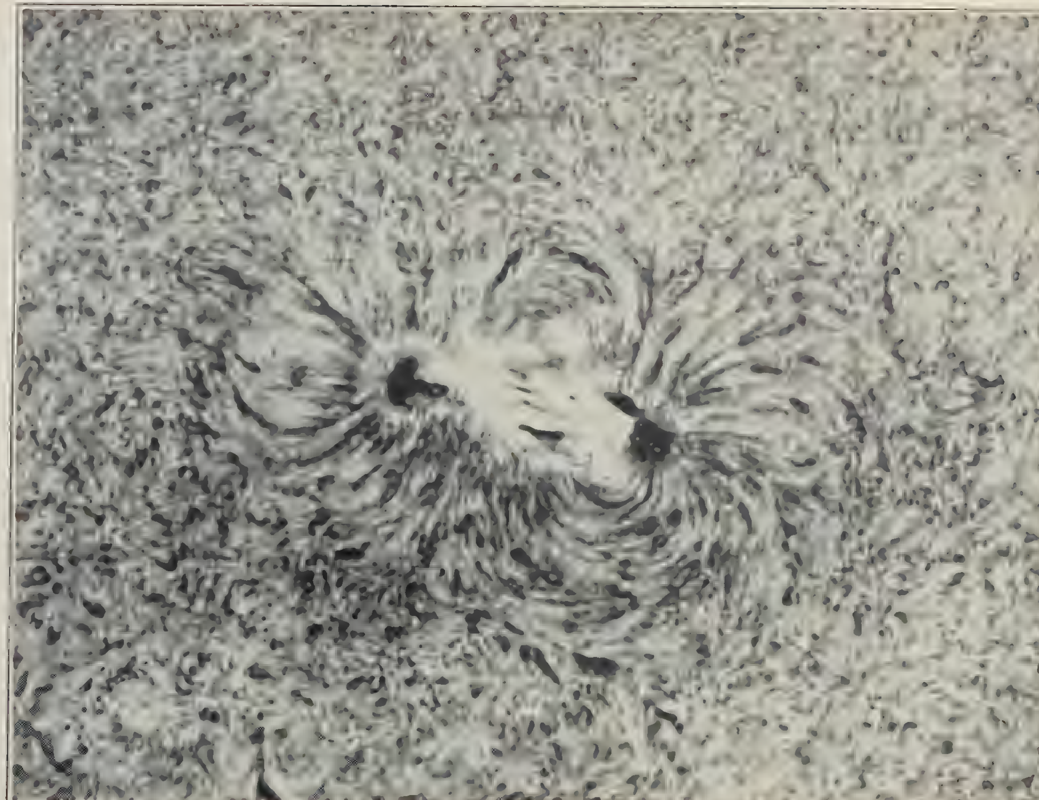
MAIN TYPES OF STELLAR SPECTRA. (MOUNT WILSON OBSERVATORY)

JOSEPH FRAUNHOFER, THE FATHER OF MODERN SPECTROSCOPY



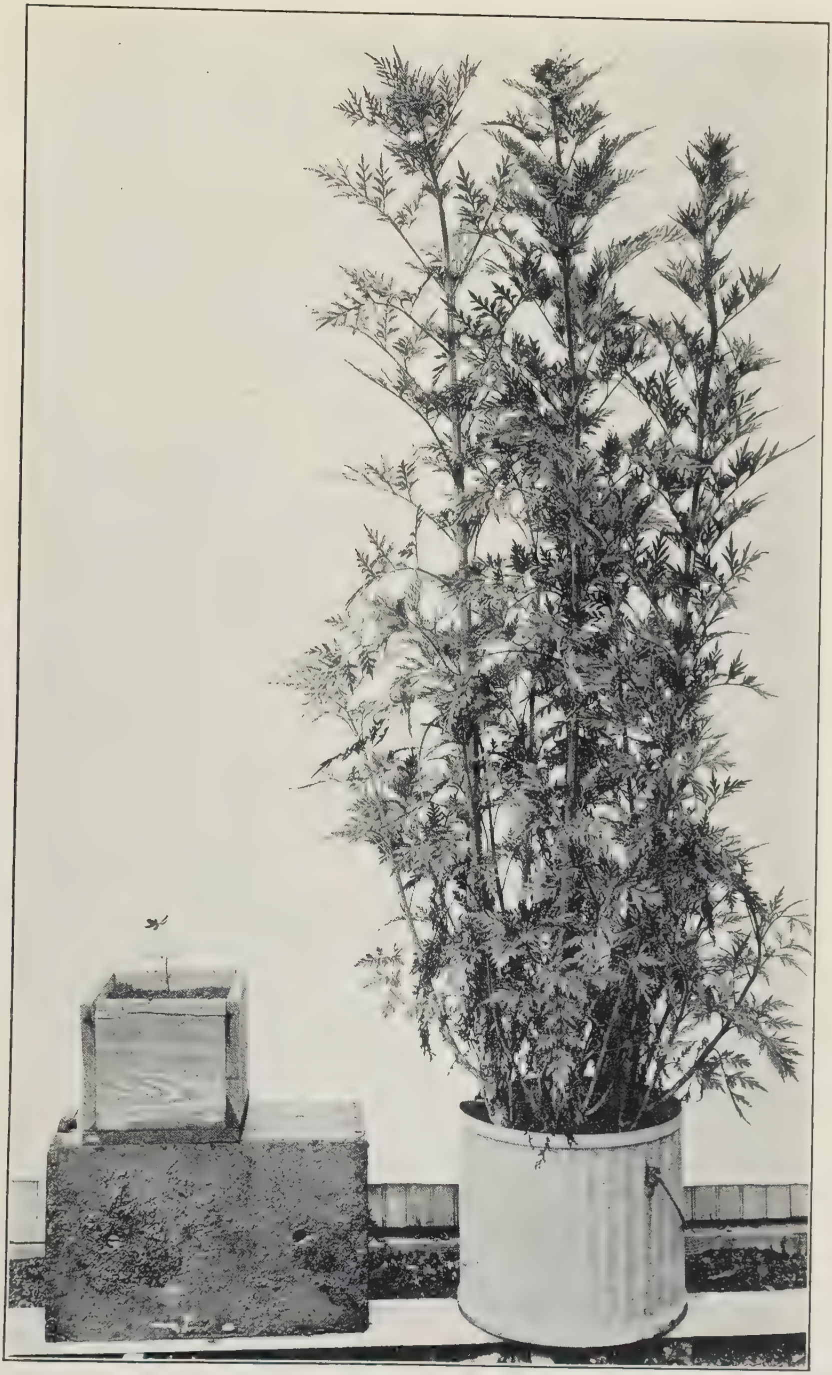
MICHELSON'S STELLAR INTERFEROMETER ATTACHED TO THE MOUNT WILSON 100-INCH REFLECTOR

THE SPIRAL NEBULA IN CANES VENATICI. (MOUNT WILSON OBSERVATORY)



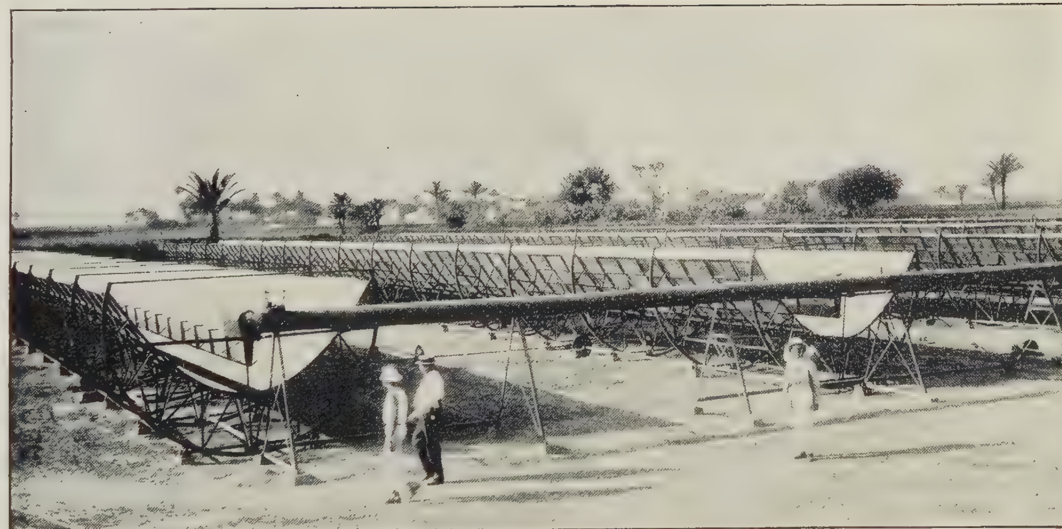
SUN SPOTS AND THEIR INFLUENCE ON THEIR SOLAR SURROUNDINGS

(From spectroheliogram by L. Humason, Mount Wilson))



THE KLONDYKE COSMOS, A TYPICAL "SHORT-DAY" PLANT

The specimens on the right, exposed full-length Washington summer days were unable to flower. That on the left, exposed only 8 hours, flowered at 8 inches high. (Work of Garner)



THE SHUMAN-BOYS SOLAR ENGINE AT MEADI, EGYPT

RECENT DEVELOPMENTS OF COSMICAL PHYSICS[1]

By J. H. Jeans

Until recent years, astronomy was concerned almost entirely with the sun, moon, and planets; the stars were mere points of light so inconceivably remote as to be of only minor interest. To-day Urania has wearied of the speck of dust we call the solar system, and claims the whole universe for her playground; the astronomer's interest centers almost exclusively on the stars. The dynamical astronomer, for example, having lost interest in the motions of the planets and their satellites, studies the arrangement and motions of the stars in the hope of discovering the general plan at least of the architecture and mechanism of the universe; for him the whole universe is a single dynamical system formed of innumerable particles—the stars—each of which attracts each other according to the universal law of gravitation.

The physical astronomer finds a different interest in the stars. For him each separate star is a complete physical system: it is a crucible in which matter is subjected to temperatures and pressures far beyond any available to the terrestrial physicist. From a study of the radiation emitted by the stars, the physical astronomer tries to unravel their physical structure, to discover how they generate their energy, and by what mechanism this energy is transmitted to their surfaces and discharged into space as radiation. In this way he may perchance happen upon properties of matter which have eluded the terrestrial physicist owing to the small range of physical conditions at his command. If the simile may be pardoned, on the plea that it is at least true to scale, the animalculæ which inhabit a raindrop may learn something of the properties of water by manipulating the particles of the raindrop with their puny strength, but they may also learn something by watching the uncontrollable fall of torrents over Niagara. The primary study of the physical astronomer is precisely this external fall of torrents over Niagara; his ultimate aim is to weld cosmical physics onto terrestrial physics so as to form one all-embracing science. Only when this has been done will it be possible to understand the main trend of events in the physical universe.

[1]A lecture delivered at University College, London, on Nov. 9, 1926. Reprinted by permission from Supplement to Nature, Dec. 4, 1926.

THE INTERPRETATION OF STELLAR SPECTRA

There is only one method available to this end, namely, a study of the radiation emitted by different stars. Apart from unscientific speculations, physical astronomy may be said to have come to birth in 1863, when Huggins attached a spectroscope to a telescope and found that certain lines in the spectra of the stars were identical with lines emitted in the laboratory by the known chemical elements. The early stellar spectroscopists believed that they were investigating "the chemistry of the stars," although we know now that they were merely opening up a fundamental problem of the physics of the stars. The spectrum of Sirius, for example, was found to exhibit hydrogen lines very strongly and calcium lines very weakly; in the solar spectrum the relative strength of these two sets of lines was reversed, calcium being strong and hydrogen weak. They concluded that hydrogen was specially prominent in the constitution of Sirius and calcium in that of the sun. Believing that Sirius must one day develop into a star similar to our sun, they conjectured that its substance must gradually change from hydrogen into calcium and other more complex elements, thus finding support for the long-established hypothesis that the more complex elements were formed by gradual evolution out of the simplest.

The true interpretation of these early observations, as the investigations of Saha, R. H. Fowler, and Milne have abundantly proved, is merely that the surface of Sirius is at a temperature at which hydrogen is specially active in emitting and absorbing radiation, while the sun's surface is at a lower temperature at which hydrogen is comparatively inert; calcium, iron, etc., having become active in its place. Just as the laboratory physicist can produce different spectra from the same vacuum tube by varying the mode and conditions of excitation, so nature produces different spectra from the same stellar material by varying its temperature.

Clearly this circumstance robs stellar spectra of all direct evolutionary significance. The spectra of the stars merely tell us their present surface temperatures, so that even if we could arrange the stars in order of age, a comparison of their spectra would only show whether their surfaces were becoming hotter or cooler; it would give no information as to chemical changes occurring in their substance.

THE SIZES OF THE STARS

The knowledge of a star's surface temperature nevertheless opens the door to further valuable knowledge. The hotter a surface is, the more energetically it radiates heat, and from a knowledge of a star's surface temperature it is easy to calculate its radiation per square

inch of surface—the sun, for example, radiates approximately 560,000 calories a minute, which is about the energy output of a 50-horsepower engine, from each square inch of its surface. The hottest stars of all probably radiate at least a thousand times as much per square inch of surface.

In this way we can estimate a star's radiation per square inch of its surface. We can also estimate the radiation from its whole surface; this can be calculated at once from its distance and apparent brightness. Simple division gives the area of the star's surface, and hence its radius and volume. Calculated stellar radii range from about three hundred times the sun's radius for Betelgeuse to about three one-hundredths times the sun's radius for the companion of Sirius.

As is well known, the diameters of certain stars have recently been observed directly with the Michelson interferometer, and the measured values agree almost perfectly with those calculated in the simple way just explained. The interferometer method is only available for the largest stars, but at the extreme other end of the scale the theory of relativity has come to the rescue. The shift of spectral lines toward the red, which Einstein predicted to be a necessary consequence of the theory of relativity, has been observed in the light received from the companion of Sirius, and its amount corresponds exactly to the radius calculated for the star in the way just explained. So much of a sensational kind has been written about the observational measurements of the diameters of Betelgeuse and of the companion to Sirius, that it may be well to remember that, while the methods were novel and of the greatest interest and importance, the results were precisely those that were generally expected, and such as a simple arithmetical calculation showed to be practically inevitable. Indeed, this calculation could only have failed in one way. It is based on the assumption that the surfaces of the stars emit their full temperature radiation like the surface of the sun. If the stars had been transparent bodies like the planetary nebulæ, or solid bodies like the moon, this assumption would have been false, and the observations would have revealed its falsity.

Our gain of positive knowledge from these observations is that Betelgeuse and the companion to Sirus are neither transparent nor solid bodies, but full radiators like the sun. Moreover, as the three stars just mentioned are about as different as any three stars possibly could be, representing approximately the two extreme ends and the middle of the scale in almost any ordered arrangement we please to make, it seems reasonable to suppose that all stars are full radiators and so, as regards their mechanism of radiation, are essentially similar structures.

THE PHYSICAL STATE OF STELLAR INTERIORS

What, then, is this mechanism of radiation? And what, as a preliminary question, is the physical state of stellar matter? In the early days of spectroscopy it was commonly supposed, from a faulty analogy with laboratory experiments, that a hot gas always gave a line spectrum, and that a continuous spectrum, such as is exhibited by the stars, could be emitted only by a solid or a liquid body. It is now generally conceded that this view was erroneous, and it is recognized that the continuous spectrum of a star merely indicates that the star is not transparent, thus leaving the question of stellar structure almost entirely open.

The view of stellar structure now universally accepted is that stars are formed of matter which, as a consequence of its high temperature, is to a very large extent broken up into its constituent electrons and nuclei, these all moving about independently like the molecules of a gas. The electrostatic attractions which in more peaceful surroundings would rapidly unite the wandering nuclei and electrons into complete atoms and molecules, are powerless in the general whirl of rapidly moving projectiles and in face of the shattering blows of the quanta of high-frequency radiation which the high temperatures of the stellar interiors generate. When I first put forward this view in 1917 (Bakerian Lecture, Phil. Trans., 218, p. 209), I thought it was entirely novel, but I have since found that in 1644 Descartes had conjectured that the sun and fixed stars were made of matter "which possesses such violence of agitation that, impinging upon other bodies, it gets divided into indefinitely minute particles." My own suggestion was not conjecture, being based on incontrovertible scientific grounds. In 1907 Emden had published calculations ("Gas Kugeln," p. 96) on the interior states of the sun and stars, in which he assumed the stars to be masses of gas resting in an equilibrium similar to that of the lower strata of the earth's atmosphere—the so-called "adiabatic" equilibrium in which there are assumed always to be sufficient currents to keep the constituent gases thoroughly mixed by a process of stirring. On this supposition he found that if the sun were composed of air or other diatomic gas of equal molecular weight, its central temperature would be 455,000,000°, while if it consisted of hydrogen, or other diatomic gas of molecular weight 2, its central temperature would be 31,500,000°. These temperatures are so high that no atom or molecule could survive them; at 31,500,000° the quantum of radiation has energy 2.1×10^{-8} ergs, which is sufficient to move an electron through a potential difference of 13,500 volts. Even with such quanta flying about, the atomic nuclei are still safe, far higher than stellar temperatures being

needed to dissociate these into their constituent electrical charges, but the electrons must of necessity nearly all be torn off atoms of moderate atomic weight and the nuclei left almost or entirely bare.

To a first rough approximation we may regard stellar matter, at any rate in the star's hot central regions, as consisting of a mixture of bare nuclei and free electrons. Passing outward toward the star's surface, the temperature falls, and we come to atoms which are more and more fully formed, until finally, close to the surface, we meet atoms which are completely formed except perhaps for one or two of their outermost electrons. In the surfaces of the coolest stars of all, we even find complete molecules, as, for example, the molecules of titanium oxide and magnesium hydride, which appear in the spectra of certain classes of stars.

THE MECHANISM OF STELLAR INTERIORS

The mixture of free electrons and bare nuclei or imperfectly formed atoms will behave like a mixture of monatomic gases. In completely broken-up hydrogen, each hydrogen molecule gives rise to four flying units—two protons and two free electrons—so that the effective molecular weight of the mixture will be 0.5. The corresponding figure for helium is 1.33, for calcium 1.90, for iron 2.07, and for lead 2.50, but since atoms of lead would not be completely broken up at stellar temperatures, the actual value for stellar lead would be somewhat higher. If we momentarily adopt 2 as a mean molecular weight of stellar matter, we find that Emden's calculations give 31,500,000° for the central temperature of the sun if formed of hydrogen molecules (mol. wt. 2). Various adjustments must be made in this figure, but they are of comparatively minor importance, and Emden's original figure of 31,500,000° is probably not very far from the actual temperature of the sun's center. Indeed, Russell has recently suggested that the great majority of stars have central temperatures fairly close to 32,000,000°. (Nature, August 8, 1925.)

One of the necessary adjustments arises from Emden's calculations having neglected the pressure of radiation in stellar interiors.[2] At 31,500,000° the pressure of radiation is about 2,500,000,000 atmospheres. Huge though this is in comparison with terrestrial pressure, it is only some 5 per cent of the ordinary gas pressure of the

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[2] I first directed attention to this in reviewing Emden's book (Astrophys. Jour., 30 (1909), p. 72), and gave a reasonably accurate estimate of the ratio of this pressure to ordinary gas pressure in stellar interiors in 1917 (Bakerian Lecture, May 17, 1917, p. 209). Some months previously Eddington had given an estimate which made this ratio some hundreds of times too large. He corrected this at the earliest opportunity (Mon. Not. R. A. S., June, 1917), but not in time to overtake sensational statements, still occasionally encountered, that pressure of radiation is of predominant importance in the dynamics of stellar interiors.

broken-up atoms and electrons at the sun's center. We could allow for its dynamical effects by decreasing our assumed mean molecular weight by 5 per cent; but this mean molecular weight is not in any case known to within 5 per cent. In exceptionally massive stars, the pressure of radiation assumes somewhat greater importance. For example, at the center of a star of some ten times the sun's mass, radiation pressure is about equal to gas pressure. To allow for its effects in this case we should have to suppose the assumed mean molecular weight halved—reduced perhaps from 2 to 1. In every case we shall get a true picture of stellar structure if we think of the layers of stellar matter as held up against gravitation by the incessant impact of a certain number of atomic nuclei or partially stripped atoms, the "molecular weight" of which is practically the same as that of the corresponding complete atoms, together with a far greater number of free electrons of standard "molecular weight" 0.00055, and a rather small number of "molecules" of radiation the molecular weight of which is negligibly small. The combined impacts of these three types of projectiles prevent the star from falling in under it own gravitational attraction.

This gives us, I think, the best snapshot picture of a star's structure. The corresponding picture of its mechanism is obtained by thinking of the nuclei as α ray particles, of the free electrons as β ray particles, and of the radiation as γ rays (although in most stars the main bulk of the radiation has the wave length of X rays); and, precisely as in laboratory work, the β rays are more penetrating than the α rays, and the γ rays are more penetrating than either.

THE TRANSPORT OF ENERGY INSIDE A STAR

In ordinary kinetic theory of gases, conduction of heat is studied by regarding the molecules of the gas as carriers of energy; each molecule has a carrying power which is jointly proportional to its heat energy, its velocity and its free path. In the interior of a star there are, as we have seen, three distinct types of carriers—the nuclei (or atoms), the free electrons, and the radiation. We can compare the relative carrying capacities of these three types of carriers by multiplying up the energy, velocity, and free path of each.

The nuclei and the free electrons have, of course, quite definite free paths. The same is true of the radiation if this is regarded as consisting of discrete quanta; when a quantum is emitted a free path begins, and when it is reabsorbed the free path ends. Whether we think in terms of undulatory theory or quanta, we may suppose that a beam of radiation is reduced in intensity by a factor $e^{-\kappa\rho x}$ on passing through a thickness x of matter of density ρ, where κ is

the "coefficient of opacity" of the matter. By comparison with the kinetic theory formula $e^{-x\lambda}$ for the reduction in strength of a shower of moving molecules, we see that the "free path" of the radiation must be taken to be $1/\kappa_{\rho}$. When we use this value for the free path of radiation and calculate carrying capacities in the way already explained, the carrying capacity of both nuclei and electrons is found to be insignificant in comparison with that of the radiation. The nuclei and electrons may have the greater amount of energy to carry, but the distance over which they carry it, their free path, is far less than that of the radiation, and their speed of transport is also less, since radiation transports energy with the velocity of light. In this way it comes about that practically the whole transport of energy from the interior of a star to its surface is by the vehicle of radiation.

This general principle was first clearly stated by Sampson in 1894 (Mem. R. A. S., 51, p. 123), but his detailed applications were vitiated by his using an erroneous law of radiation. Twelve years later, Schwarzschild independently advanced the same idea (Gött. Nach., 1906, p. 41); he showed how the temperature of any element of a star's interior must be determined by the condition that it received just as much radiation as it emitted, and gave accurate equations of radiative equilibrium which have formed the basis of every subsequent discussion of the problem.

THE CONFIGURATION OF A STAR IN EQUILIBRIUM

As a consequence of radiation completely outstripping the material carriers in the transport of energy to the star's surface, the build of a star is entirely determined by the values of k, the coefficient of opacity in its interior. If this coefficient is everywhere zero, the star is entirely transparent, and so can not retain any heat; we now have a star of zero temperature and therefore of infinite extent. If, on the other hand, the coefficient of opacity is everywhere infinite, the star is completely opaque, so that all radiation accumulates where it is generated until the star's temperature becomes infinite, and we have a star of infinite temperature but of infinitesimal radius. It is, of course, the intermediate values which are of practical interest, but the two extreme cases just mentioned show how the whole build of a star depends on the value of the opacity coefficient k. So much is this the case that all attempts to investigate the build of stars before the value of this coefficient was known can only be regarded as speculation.

The first attempt to evaluate it theoretically by Eddington in 1922 (Mon. Not. R. A. S., 83, p. 32) proved unsuccessful and was

withdrawn. In the next year Kramers (Phil. Mag., 46, p. 836) put forward the theory of opacity which has now gained general acceptance. Using the value of the opacity coefficient given by this theory, it is possible to determine the complete build of a star having any given mass and any given rate of generation of energy. In this way I have shown (Mon. Not. R. A. S., 85, pp. 196 and 394) that a star of given mass can rest in equilibrium with any radius from zero to infinity, different radii corresponding to different rates of generation of energy from zero to infinity by the star. A star adjusts its radius to suit its rate of generation of energy, and in so doing fixes its surface temperature and spectral type. If a star's rate of generation of energy were suddenly to change, the star would expand or contract until it had assumed the radius and temperature suited to its new rate of generation of energy. Contrary to common belief, an increase in a star's rate of generation of energy causes it to contract its radius and increase its temperature, while a slackening in its generation of energy is found to result in expansion and cooling. Thus we see the giant red stars such as Betelgeuse do not owe their immense size to their radiating so much energy, but to their radiating so little; indeed, comparatively compact stars such as Plaskett's star and V Puppis are radiating far more in proportion to their masses. The general theoretical principle can be verified by the examination of pairs of stars of approximately equal mass, as, for example, the two pairs in the following table. The surface temperatures are here deduced directly from the observed spectra, the radii then being calculated in the way already explained.

Star	Mass (in terms of sun)	Generation of energy per gram (ergs per second)	Observed temperature	Radius (in terms of sun)
Sun	1.00	1.9	5,750	1.00
α Cent. B	.97	1.4	3,700	2.03
Procyon	1.13	10.2	8,300	1.17
α Cent. A	1.14	2.3	5,000	1.56

STELLAR EVOLUTION

There is not likely to be any abrupt change in the rate of generation of energy of an actual star. There will be a slow secular decrease, but this will be associated with a slow secular decrease of the star's mass resulting from its continual emission of radiation. For example, the 560,000 calories of radiation which stream out every minute from each square inch of the sun's surface have a mass of 2.5×10^{-8} gm., whence it is readily calculated that the sun's mass

must diminish by 250,000,000 tons every minute. After millions of millions of years this rate of wastage produces an effect even on the gigantic mass of the sun. To trace the changes in the radius and temperature of an actual star we must study the sequence of configurations assumed in turn as the mass and the rate of generation of energy change together. In this way I have found (Mon. Not. R. A. S., January, 1925) that a normal star would first decrease in size and get hotter, but would ultimately expand and get cooler again. This result provides a simple dynamical interpretation of the sequence of "ascending and descending temperatures" which was first suggested by Lockyer, and formed the outstanding feature of Russell's 1913 theory of stellar evolution—although our physical interpretation is very different from that suggested by Russell.

THE ATOMIC WEIGHT OF STELLAR MATTER

In the simplest case, in which energy is generated uniformly throughout a star's mass, the surface temperature T assumed by a star of mass M and of given luminosity (or rate of generation of energy) is given by the equation—

$$\text{Star's luminosity} = C\left(\frac{N^2}{A}\right)^{-0.8} T^{0.8}\mu^{0.8}f(M)$$

Here C is a known constant, N and A are the atomic number and atomic weight of the stellar atoms, and μ the effective molecular weight (about 2) of the broken-up stellar material; T is the temperature of the star's surface and $f\ (M)$ is a quantity I have calculated and tabulated, which depends only on the star's mass (Mon. Not. R. A. S., 85, p. 395).

The quantity N^2/A necessarily occurs in the foregoing formula, because the coefficient of opacity, by which the star's whole structure is determined, is proportional to N^2/A. If a Maxwell demon could cut every atomic nucleus in a piece of matter into two equal halves, he would halve both N and A and so also N^2/A, with the result that the substance would become twice as transparent as before. This shows that a large clot of matter in the form of a massive nucleus is far more effective in absorbing X radiation than a large number of small clots of equal total mass. It is for this reason that the physicist and surgeon both select lead as the material with which to screen their X-ray apparatus; a ton of lead is far more effective in stopping unwanted X rays than a ton of wood or of iron. If we knew the strength of an X-ray apparatus, and the total weight of shielding material round it, we could form a very fair estimate of the atomic weight of the shielding material by measuring the amount of X radiation which escaped through it.

A very similar method may be used to determine the atomic weight of the atoms of which the stars are composed. A star is in effect nothing but a huge X-ray apparatus. We know the total mass of many stars, and we can readily calculate the rate at which they are generating X rays—it is merely the rate at which they are radiating energy away into space. If we could shut our Maxwell demon inside a star and make him cut each atomic nucleus in half, keeping the star's mass and rate of generation unaltered, we should halve the coefficient of opacity of the star. This would necessitate a change in the star's build; in actual fact its radius would increase fourfold while its surface temperature would be halved. We could follow the progress of the demon's work by watching the changes in the surface temperature of the star. Hence from the observed surface temperature of any star the mass and luminosity of which are known, it must be possible to estimate the atomic weight of the atoms of which the star is composed. The formula given above provides the means.

I ought perhaps to mention in passing that Eddington and others have approached this question from the other end, assigning conjectural values to N^2/A from our knowledge of the elements which occur in the atmospheres of the sun and stars. Such a course appears to be very risky. A star's spectrum gives no indication of the selection of elements which occur in its interior; and there is at least an a priori possibility that the elements occurring there may be entirely different from those which appear in its surface; consider into what errors an extra-terrestrial observer might be led if he assumed that the earth contained no chemical elements beyond those appearing in its atmosphere.

When, however, the risk has been taken, and such values assigned to N^2/A, all the quantities which occur in the luminosity formula are known, and the only question which remains is whether the values calculated for the luminosity agree with those observed through the telescope. They do not.

It is clear that the value of N^2/A must be adjusted until agreement is obtained, and this amounts to precisely the same thing as determining N^2/A, directly and at once, from the luminosity formula. On doing this for a series of stars, I have found (Mon. Not. R. A. S., June, 1926) that two very significant facts emerge. First, most of the values so determined prove to be higher than the value for uranium, the heaviest element known on earth. Second, the different values of N^2/A show an ordered arrangement, the youngest stars generally giving the highest values for N^2/A, and this value falling as we pass to older stars.

The second of these results has far-reaching implications. Contrary to the views of the early spectroscopists, and contrary to what

is still probably the prevalent belief, it now looks as though the atoms in a star become simpler as the star grows older; evolution appears to be from complex to simple, and not, as in biology, from simple to complex. There is at present no direct experimental evidence bearing on this question except that provided by radioactivity, where evolution is certainly from complex to simple, atoms of lower atomic weight being continually produced by the disappearance of atoms of higher atomic weight.

The evidence of physical astronomy, pointing to an evolution of matter in the same direction, suggests that the main evolution of matter in the universe may be of the same type as, but a generalization of, the radioactive processes as they occur on earth. The evidence so far given has been based entirely on Kramers' theory of opacity for X radiation. This theory has been found to agree very well with the observed absorption in the laboratory of radiation of about the wave-length which occurs in stellar interiors, while its theoretical basis has been discussed fully and critically by Eddington, Milne, and others, who have been unable to suggest any substantial alteration. Still, if the evidence from Kramers' formula were the only evidence available, our conclusions would be open to the charge of resting, if not on a slight, at least on a single, foundation. But there is plenty of further evidence, as we shall now see.

DISTRIBUTION OF CHEMICAL ELEMENTS IN A STAR

A star necessarily arranges itself so that there is a great concentration of matter near its center. This is primarily a consequence of the inverse square law of gravitation, although the opacity law is involved also to some extent. With Kramers' formula for the opacity the arrangement is such that the central density is one hundred or more times the mean density, while at least some 90 or 95 per cent of the star's total mass is concentrated in a sphere of half the radius, and so of only one-eighth the volume, of the star. But the degree of central condensation is rather insensitive to changes in the opacity formula, and any reasonable formula would still give very high central condensation. A strict mathematical argument based on this circumstance (Mon. Not. R. A. S., June, 1926, p. 561) enables us to rule out the possibility of convection currents stirring up a star's interior in the way in which boiling water is stirred up in a kettle. Convection occurs in a kettle because the hot water at the bottom is of lower density than the cool water at the top; it is absent in a star because the hot matter near the center, notwithstanding its intense heat, is still far, far denser than the cool matter near the surface. Thus, the mixture of matter in a star's interior is not analogous to that in the earth's lower atmosphere, where the constituent gases are kept thoroughly mixed by winds and storms,

but rather to a serene upper atmosphere in which the lightest elements float to the top while the heaviest sink downward under gravity.

Such considerations as these suggest at once that the elements which indicate their presence in the spectra of the outermost layers of the sun and stars are only the very lightest of the series of elements existing in the star. It is natural that the earth, formed originally out of the sun's outer layers, should contain precisely the same chemical elements as these outer layers, but it now appears that there ought to be heavier elements inside. The calculation which assigns to stellar matter atomic numbers higher than that of uranium no longer looks suspicious or paradoxical; it begins to look natural, and indeed almost inevitable.

THE GENERATION OF ENERGY IN A STAR

Further evidence that the atomic weights of stellar atoms are higher than those of any known terrestrial atoms may be obtained by considering the rate of generation of energy inside a star. The sun radiates energy at about 2 ergs per second for each gram of its mass, and so must generate energy at this rate in its interior. To the best of our knowledge it has generated and radiated at this, or a greater, rate for some millions of millions of years. Could the sun have any such radiating capacity if its interior were formed of the common terrestrial elements, calcium, iron, silicon, etc.?

One's first impulse is to say, "No." Even if the sun were built of pure uranium, its radiating power would be only about one-half of that observed, and would only last for a minute fraction of what is believed to have been the sun's life. A sun of pure radium would radiate more than enough for the moment, but its life would be limited to a few thousand years. No possible combination of terrestrial elements can give the combination of high radiation and of staying power which is observed in the sun and stars.

We must, however, remember that stellar interiors are at pressures and temperatures which are quite unattainable in our laboratories. We are led to wonder whether our terrestrial elements would behave quite differently if they were exposed to stellar conditions. Is it possible, for example, that the sun's interior is formed of ordinary terrestrial elements, which owe their high generation of energy merely to their high temperatures and pressures?

A general survey of astronomy throws a good deal of light on this question. We find immediately that the stars which radiate most energetically (per unit mass) are not, broadly speaking, the hottest stars, and neither are they the densest. Some of the hottest and densest stars are entirely put to shame in the matter of radiation by very cool stars of low density such as Antares and Betelgeuse.

If we arrange the stars in order of radiation per unit mass, we shall find that we have arranged them neither in order of temperature nor of density, but very approximately in order of age; the youngest stars radiate most energetically, regardless of their interior temperatures and density; the older stars appear to be tired out.

The general tendency is shown in the following table:

Star	Generation of energy (ergs per gram)	Central temperature	Central density	Age
Plaskett's star	1000	500,000,000	Very great	Less than 10^{11} yr.
V Puppis	640	300,000,000	More than 1,000	
Antares	320	1,000,000	0.005	
Capella A	50	8,000,000	0.5	Less than 10^{12} yr.
Sirius	21	150,000,000	1,000	10^{12} yr.
Sun	1.88	70,000,000	300	7×10^{12} yr.
α Cent. B	1.39	15,000,000	10	7×10^{12} yr.
Kruger 60 B	0.02	70,000,000	30,000	Very old.
Sirius B	0.003	Unknown.	More than 53,000	Unknown.

If it is asked whether densities so high as these can really exist at the centers of the stars, the answer is provided by the companion to Sirius (Sirius B). Direct observation has shown that the mean density of this star is about 53,000, and the central density must of course be higher. Incidentally, as Eddington has remarked, this provides striking confirmation of our view that stellar matter consists of atoms broken up into their fundamenal constituents. It is impossible to compress matter formed of complete atoms of radii 10^{-8} cm. or more to anything approaching these high densities, but there is no difficulty as regards minute nuclei and electrons of radii of the order of 10^{-13} cm.

It has to be admitted that many of the entries in the table are highly conjectural, and few can claim any great accuracy. But while many astronomers may prefer different values for individual entries in the table, I doubt if any would seriously challenge the general contention that a star's energy-generating capacity depends primarily on its age, and not, at any rate primarily, on its central temperature or density.

No doubt exceptions to the general rule can be found. An extreme example is provided by the earth and sun; the matter of which these two bodies are formed must be of the same ultimate age, yet they radiate at very different rates per unit mass. This is readily explained if we suppose the heavy atoms from which the sun's energy originates to have sunk deep into its interior, and so not to have entered into the composition of the earth and planets. A similar explanation will account for the different radiating capacities of the components of binary systems. But these exceptions result from special conditions prevailing in special cases; they do not affect the

general law that a star's generation of energy is not determined by either its density or its temperature.

The accompanying table shows that the law is well supported by observational astronomy; it can also be reached from a theoretical study of the actual process of generation of energy in a star. A mass of evidence, mostly dynamical, indicates that the stars must have existed for millions of millions of years. To take one example, newly formed binary stars have circular, or nearly circular, orbits; this is a consequence of the manner of their formation. Every gravitational pull on a circular orbit tends to make the orbit more elliptical, so that the older a binary star is, the more elliptical its orbit ought to be. This is actually found to be the case. But from our general knowledge of the number and masses of the stars wandering about in space, we can estimate the rates at which the ellipticities of the orbits of binary stars ought to increase, and this in turn makes it possible to estimate the ages of actual stars. It is a mere problem of dynamics, and the answer comes out in millions of millions of years.

We can now estimate the total amount of radiation which must have been emitted by particular stars in the millions of millions of years they have existed; and, except in the case of the youngest stars of all, the total mass of this radiation is found to be far greater than the present mass of the star. We obtain the mass of the star at its birth by adding the mass of all this radiation to that of the matter now remaining in the star. Thus its mass at birth must have been far greater than now. But, as a star's mass at any instant consists almost wholly of the mass of the matter of which it is composed, we see that the greater part of the matter contained in the original star has ceased to exist as matter; it has been annihilated and transformed into radiation which the star has radiated away into space. So far back as 1904 (Nature, 70, p. 101) I put out the suggestion that energy might be created by the annihilation of matter; it now appears that this process must in actual truth be the source of the energy emitted by the sun and stars. Throughout a star's interior electrons and protons must at intervals fall into one another and mutually destroy one another, the energy of their fall being set free as radiation.

The energy of this fall is enormous, being sufficient to set both the masses involved into motion with a velocity of 0.866 times that of light. In no other way can a given mass of matter be made to yield energy of amount comparable with this; for example, whereas the ordinary combustion of a ton of coal provides energy enough to drive an express locomotive for an hour, the annihilation of a ton of coal would provide enough energy for all the heating, lighting, power, and transport in Great Britain for a century.

Each proton or atom, as it is annihilated, makes a splash of radiant energy which travels through the star until, after innumerable absorptions and reemissions, it reaches the star's surface and wanders off into space. Each splash is similar to the splashes produced by radioactive material in the spinthariscope, except for being many thousands of times more powerful. The great energy of the splashes is to some extent counterbalanced by their rarity. In the sun, for example, only about 1 atom in every 10^{17} annihilates itself each hour. A cubic centimeter of the sun's mass contains, let us say, 10^{22} atoms, and of these about 100,000 are annihilated every hour. The energy produced in a cubic centimeter of the sun's mass is thus not very great, averaging about 9,400 ergs or 0.00022 calorie per hour; the enormous flow of energy from the sun's surface results from the fact that all the energy produced in a cone 433,000 miles in depth has to stream out through the mouth of this cone.

Such, in brief, is the mechanism by which stellar energy is generated. The question immediately before us is whether this generation of energy proceeds more merrily, whether the electrons and protons fall into one another more frequently, when the stellar matter is in a state of high temperature and high density.

It is a matter of direct observation that ordinary radioactive processes can not be either inhibited or intensified by such temperatures as are available in the laboratory; the quantum theory provides the reason. Einstein has shown how a subatomic generation of radiation can occur in either of two ways, spontaneously or through the stimulus of incident radiation, and it is easy to calculate the temperature at which the second process becomes operative. It is found that the quantum of radiation at this temperature must have energy equal to the energy set free by the subatomic change in question. The temperature necessary to expedite the disintegration of uranium is in this way found to be of the order of 120,000,000,000 degrees, and it at once becomes clear why warming up uranium in the laboratory can not speed up its disintegration. A similar calculation shows that the temperature necessary to influence the rate of subatomic annihilation of matter is of the order of 7,500,000,000,000 degrees. It may be argued that a lower temperature, although not adequate to bring about the actual annihilation of matter, might set up subatomic processes of adequate intensity. This is true as regards a star's momentary radiation, but such processes can not provide an adequate duration for the radiation. All processes which are affected by temperatures of less than about 7,500,000,000,000 degrees leave the total number of electrons and the total number of protons in a star unaltered, whereas the whole evidence of astronomy is that

the number of electrons and protons in a star must continually decrease.

With this figure before us, it is clear that the comparatively feeble stellar temperatures of less than 1,000,000,000 degrees must be quite inoperative in regard to the main generation of stellar energy; indeed, the heat of the hottest of stellar interiors can have no more influence on the rate of annihilation of matter than a warm summer's day has on the rate of disintegration of uranium. Thus it seems abundantly clear that what is annihilating the matter of the stars is neither heat nor cold, neither high density nor low, but merely the passage of time.

These considerations notwithstanding, it has been suggested by Russell (Nature, August 8, 1925), whose ideas were afterwards adopted by Eddington (Nature, May 1, 1926), that the annihilation of matter (which they agree to be the ultimate source of stellar radiation) may be produced by the raising of ordinary matter to a critical temperature of some thirty or forty million degrees. Russell suggests that matter is, broadly speaking, inert until it reaches this critical temperature, when an unlimited transformation of matter into radiation suddenly takes places.

In addition to running foul of the physical principles just explained, this suggestion encounters the difficulty that the generation of energy it provides would not only be unlimited but also illimitable; when once it began there would be no stopping it. The proposal of Russell and Eddington would, in effect, make matter thermodynamically unstable at stellar temperatures by endowing it with the properties of an explosive at its flash point. When once stellar matter reached its flash point, its resulting annihilation would generate so much heat that the adjacent matter would also in turn be raised to the flash point, and the whole star would almost instantaneously explode into radiation. The sky would show no steady starlight, but merely a succession of apparitions of novæ of the most terrifying kind, as the various stars reached their flash points and "popped off" in turn. In spite of the astronomical eminence of its father and stepfather, I, for one, find it impossible to accept a hypothesis which is not only contrary to the general principles of physics but also against which the very stars fight in their courses.

A general mathematical discussion of the stability problem shows that a star built of matter the rate of generation of energy of which is absolutely unaffected by changes of temperature and density will be dynamically stable. But such a star, although stable, has not much stability to spare. If we change the properties of our stellar matter in the sense of making an increase of temperature increase the rate of generation of energy, we lessen the already small margin

of stability. Any substantial step in this direction would render the star dynamically unstable.

Combining this purely dynamical result with the physical principles already explained, it becomes clear that we may, to a good first approximation at least, suppose that an increase in the temperature of stellar matter produces no increase at all in its rate of generation of energy.

Stellar radiation must either originate in types of matter known to us on earth or else in other and unknown types. When once it is accepted that high temperature and density can do nothing to accelerate the generation of radiation by ordinary matter, it becomes clear that stellar radiation can not originate in types of matter known to us on earth. Other types of matter must exist and, unless physics and chemistry have gone very far astray in recent years, these other types can only be elements of higher atomic weight than uranium. The significance of the calculation which showed that stellar atomic weights are, in the main, higher than that of uranium now becomes apparent.

RECAPITULATION AND INTERPRETATION OF RESULTS

We have now reached the conclusion, by three distinct paths, that the atomic weights of stellar atoms must in the main be higher than that of uranium:

(1) By direct calculations from Kramers' formula.

(2) From the consideration that the atoms near the center of a star must be substantially heavier than those near its surface.

(3) From the consideration that atoms of atomic weight less than uranium, no matter how much they were heated or compressed, could not provide the intense and lasting radiation emitted by the stars.

The atomic weights of stellar atoms are not only found to be higher than that of uranium but also they vary systematically from star to star. In brief, the youngest stars are found to have the highest atomic weights, and with this clue all the pieces of the puzzle are found to fit together.

We have to suppose that matter in its earliest state consists of a mixture of elements of different atomic weights, those elements the atomic weights of which are highest having the greatest capacity for the spontaneous generation of radiation by annihilating themselves, and, in consequence, having the shortest lives. These elements will be the first to disappear as the star ages, their disappearance reducing not only the mean atomic weight in the star but also the mean rate of radiation per unit mass, since these heavy elements are the most energetic radiators. Just as, on the coast, the hardest rocks survive for longest the disintegrating action of the sea, so in a star

the lightest elements survive for longest the disintegrating action of time, so that ultimately the star contains only the lightest elements of all and so has lost all radiating power. Our terrestrial elements have so little capacity for spontaneous transformation that they may properly be described as "permanent." Calculation shows that if they underwent any appreciable transformation in periods comparable with the life of a star (say 10^{13} years) the spontaneous generation of heat by the earth's mass would make the earth too hot for human habitation. The radioactive elements are, of course, an exception; they probably represent the last surviving vestiges of more vigorous primeval matter, and so form a bridge between the inert permanent elements and the heavier and shorter-lived elements of the stars.

An interesting question is whether the heavy atoms change into radiation instantaneously, or only through successive stages of transformation. Astronomical evidence makes it fairly certain that the most massive stars contain more atoms than our sun, there being a wider range in the weights of the stars than in the atomic weights of their atoms. As these stars must in time become reduced to the mass of our sun, the process of evolution clearly calls for an actual annihilation of atoms; it is not enough to postulate a mere gradual decrease in the atomic weight of each atom until it ends as a permanent atom. Radioactivity suggests that this latter process may also occur, but the evidence of astronomy is that it is at best a subsidiary process.

The number of "permanent" atoms in a massive star such as Antares or V Puppis can not undergo any perceptible diminution in the next 10^{13} years, so that they must all survive in the final star of mass perhaps only a fiftieth of that of the present star. Thus some 98 per cent of the present masses of these stars must consist of non-permanent atoms. To put it in another way, the present mass of a star such as Antares or V Puppis must consist, as regards 98 per cent, of atoms which are destined to change into radiation, and as regards only 2 per cent, of atoms which can not change into radiation. Clearly the primary matter of the universe must be of non-permanent type; our terrestrial atoms are a mere residue of non-transformable ashes. Like the animalculæ of the raindrop looking out on to Niagara, we discern that our physics and chemistry are only the fringes of far-reaching sciences; beyond the seashore we have explored in our laboratories lies the ocean the existence of which we are only just beginning to suspect.

We are thus led to picture the youngest stars as formed of matter practically all of which is unknown on earth, being of atomic weight higher than that of uranium. This possesses the capacity of annihi-

lating itself spontaneously, the energy produced in the process being set free as radiation. Its rate of generation of energy, as estimated from the luminosities of the youngest stars, is of the order of 1,000 ergs per gram per second. As the annihilation of 1 gram of matter produces 9×10^{20} ergs of energy, the matter must have a "period of decay" of 9×10^{17} seconds, or about 30,000 million years. As the star ages, and only less transformable matter remains, the period of decay is correspondingly lengthened. The matter in the sun, radiating 2 ergs per gram per second, must have a period of decay of 15,000,000 million years. It is these periods of decay which determine the rates of evolution and length of life of the stars. Broadly speaking, a star lasts as long as the atoms of which it is composed, and the lives of these atoms are constants of nature.

We notice that the periods of decay of stellar atoms are long compared with the periods of ordinary radioactive decay, suggesting that the radioactive elements are mere transitory formations in the evolution of the elements.

THE CRITICAL CENTRAL TEMPERATURE

A group of stars selected for having approximately equal masses—as, for example, the sun, Procyon, and the two components of α Centauri—might be expected a priori to have very different rates of generation of energy, with the result that the stars would have very different surface temperatures and also very different central temperatures. Indeed, on first approaching the question, the whole range of temperatures from zero to infinity would seem to be open for each of these quantities. Yet in actual fact the surface temperatures of the four stars mentioned, as also of all stars of the same mass, lie within the narrow range between 3,700 and 8,300 degrees; their central temperatures probably lie within the range from 15,000,000 to 100,000,000 degrees. For stars of other masses the limits are different, and are substantially wider for stars of great mass. But the stars of any definite mass always show a definite upper limit of temperature, both for the surface temperature and for the central temperature. These limits are never exceeded, but the majority of stars of the particular mass in question seem to crowd toward them. The existence of one limit, of course, implies the existence of the other, and it seems likely that the limit to the central temperature is the more fundamental. Stars having the same mass as our sun never have central temperatures higher than 80,000,000 degrees, while the majority have central temperatures not very far below 80,000,000 degrees. For stars 20 times as massive as our sun, the corresponding limit is probably somewhere about 300,000,000

degrees, while there are intermediate limits for stars of intermediate mass.

This is obviously one of the fundamental facts of physical astronomy: What does it mean? The normal event for a star like V Puppis, losing mass and capacity for generation of energy together, would be a gradual shrinkage of size accompanied by a steady increase of central temperature. What is it that checks this normal course of evolution so soon as the central temperature touches 300,000,000 degrees?

I have recently suggested that the upper limit of temperature for any star is simply that at which its central atoms begin to be stripped nearly or entirely bare of electrons. This is merely a matter of simple calculation, but we have to suppose the atoms at the star's center to have the high atomic weights which other considerations, as we have seen, assign to them. For example, a temperature of 300,000,000 degrees suffices to strip the last electrons off atoms of atomic weight 300 or more. The fall in the critical central temperature as a star gets older and less massive is, on this view, a direct consequence of the decrease in the atomic weight of the stellar material, which occurs as the heaviest atoms gradually annihilate themselves.

It remains to explain why this temperature constitutes an upper limit, why a star can not go on getting hotter after its innermost atoms are stripped bare of electrons. So far as I can see, only one answer is possible: The stripping of the electrons from an atom must remove its power of annihilating itself, and so must inhibit its capacity for generating radiation. The central atoms of the star now act precisely like the governor of a steam engine, regulating the generation of energy so that the central temperature is kept close to the critical temperature. If the star begins to get too hot, the central atoms become stripped bare of electrons, and so leave off generating energy. The star then begins to cool off, and as it does so the atoms reform and resume their generation of energy, again heating up the star. The mechanism provides a perfect thermostat, and it is easily shown that its action is stable. As a star ages the heavier atoms at its center are the first to be transformed into radiation and so to disappear; their place is taken by lighter atoms, and as a lower temperature suffices to strip these lighter atoms bare of electrons, the critical central temperature of the star falls.

An interesting confimation of this hypothesis is provided by the components of newly formed binaries. These have the high energy-generating capacity per unit mass of young stars, associated with the small mass appropriate to much older stars. Clearly the "governor" action ought to be particularly active in checking the generation of energy in these stars, so that they ought to have central

temperatures close up to the maximum for their mass. This is in actual fact found to be the case.

All the evidence at present available points to the annihilation of matter being a quantum phenomenon; possibly it represents nothing more than the spontaneous drop of an electron to a zero-quantum orbit. This would suggest an explanation of why bare nuclei and free electrons should be immune from annihilation, and hence why atoms stripped bare of electrons can not generate energy.

HIGHLY PENETRATING RADIATION

If our earth exhibits only one end of the chain of chemical elements, where shall we look for the other end? Moving backwards along the evolutionary sequence we come to younger and yet younger stars, containing elements of higher and higher atomic weight. Passing beyond the stars altogether we come to the nebulæ; here we ought to find the elements of highest atomic weight of all, and the matter of greatest radiating capacity.

Visually the nebulæ are extremely faint objects; their emission of visual radiation per unit mass is only about equal to that of our sun. There is, however, an essential difference between the radiation generated in the stars and that generated in the nebulæ. Radiation, when first generated, must have enormous penetrating power; the simultaneous annihilation of a single electron and proton produces radiation of wave-length only 1.3×10^{-13} cm. The high penetrating power of this short wave-length radiation, nevertheless, only suffices to carry it through a small fraction of the radius of a star, and successive absorptions and remissions soften it, by a sort of generalized Compton effect, until it finally emerges from the surface of the star as ordinary temperature radiation. The density of the nebulæ is, however, so much lower than that of the stars that similar radiation, when generated inside a nebula, passes almost unchecked directly into outer space. Here and there the radiation may devastate isolated atoms in its passage, ejecting a few million-volt electrons in the process, but the majority of it will pass on unhindered until it meets a medium of substantial absorbing powers. Thus we should expect the atmospheres of the stars, sun, and earth, and even the solid body of the earth, to be under continual bombardment by highly-penetrating radiation of nebular origin.

Such radiation has been detected in the earth's atmosphere by Kolhörster, Millikan, and many others, who are satisfied that it is of extra-terrestrial origin. If it originated in the stars, the amount received would depend largely upon the position of the sun. As it does not, the radiation must originate in nebulæ or cosmic masses other than stars. Quite recently (Nature, October 9, 1926), Kol-

hörster and von Salis have found that its intensity varies with the position of cosmic masses, in a way which indicates that the radiation is received largely from regions near the Milky Way, especially the regions of Andromeda and Hercules.

I have calculated that the total amount of highly-penetrating radiation actually received is of the order of twice that which ought to be received from the Andromeda nebula alone (Nature, December 12, 1925) if this consisted solely of matter of the same radiating power as the very youngest of the stars. Clearly the total amount of radiation which is observed to be received on earth is of the right order of magnitude; it is, moreover, so large that it is difficult to imagine any possible origin for it other than that just mentioned. Its penetrating power appears to be rather less than might have been expected if it originated in the actual annihilation of electrons and protons, but I do not think the difficulty, if it exists, is insuperable. Quite recently Rosseland (Astro. Journ., May 1926) has suggested that bombardment of this radiation may be the cause of the observed bright lines in stellar spectra; I had previously (Nature, December 12, 1925) suggested a similar origin for the luminosity of the irregular nebulæ.

There is a temptation to try to probe still further into the physics of the nebulæ, to try to understand the properties of matter in its still earlier forms, perhaps even to get a glimpse of it in the actual process of creation. But to yield to this temptation would carry us too far into the realms of conjecture and speculation. So far the course of our argument has not depended on either conjecture or speculation. Where there has appeared at first to be a choice of ways, all ways except one have proved on further examination to be prohibited either by observational knowledge or by well-established principles of physics or dynamics: there has never been any real choice. For this reason the conclusions we have reached, although certainly novel and perhaps unexpected, appear to me to be, in their main lines, inevitable; I can see no means of escape.

LIFE AND THE UNIVERSE

A general survey of the results obtained by cosmical physics has suggested that terrestrial laboratory physics is a mere tail-end of the general science of physics. The primary physical process of the universe is the conversion of matter into radiation, a process which did not come within our terrestrial purview at all until 1904. The primary matter of the universe consists of highly dissociated atoms, a state of matter which, again, was not contemplated before 1917. The primary radiation of the universe is not visible light, but short-wave radiation of a hardness which would have seemed incredible at the beginning of the present century.

Indeed, our whole knowledge of the really fundamental physical conditions of the universe in which we live is a growth of the last quarter of a century.

The simple explanation of this situation is to be found in the fact that life, naturally enough, begins its exploration of Nature by studying the conditions which immediately surround it; the study of the general conditions of the universe as a whole is a far more difficult task which life on this planet is only now approaching. Now the physical conditions under which life is possible form only a tiny fraction of the range of physical conditions which prevail in the universe as a whole. The very concept of life implies duration in time; there can be no life where the atoms change their make-up millions of times a second and no pair of atoms can ever become joined together. It also implies a certain mobility in space, and these two implications restrict life to the small range of physical conditions in which the liquid state is possible. Our survey of the universe has shown how small this range is in comparison with the range of the whole universe. Primeval matter must go on transforming itself into radiation for millions of millions of years to produce an infinitesimal amount of the inert ash on which life can exist. Even then, this residue of ash must not be too hot or too cold, or life will be impossible. It is difficult to imagine life of any high order except on planets warmed by a sun, and even after a star has lived its life of millions of millions of years, the chance, so far as we can calculate it, is still about a hundred thousand to one against its being a sun surrounded by planets. In every respect—space, time, physical conditions—life is limited to an almost inconceivably small corner of the universe.

What, then, is life? Is it the final climax toward which the whole creation moves, for which the millions of millions of years of transformation of matter in uninhabited stars and nebulæ, and of waste radiation into desert space, have been only an incredibly extravagant preparation? Or, is it a mere accidental and possibly quite unimportant by-product of natural processes, which have some other and more stupendous end in view? Or, to glance at a still more modest line of thought, is it of the nature of a disease which affects matter in its old age, when it has lost the high temperature and capacity for generating high-frequency radiation with which younger and more vigorous matter would at once destroy life? Or, throwing humility aside, is it the only reality, which creates, instead of being created by, the colossal masses of the stars and nebulæ and the almost inconceivably long vistas of astronomical time? There are too many ways even to enumerate of interpreting the conclusions we have reached; I do not, however, think there is any one way of evading them.

THE EVOLUTION OF TWENTIETH CENTURY PHYSICS[1]

By Robert A. Millikan

My own period of activity in the intensive pursuit of physics happens to be almost exactly coincident with the period of development of what we may call modern physics as distinct from nineteenth century physics; so that I am in the rather unusual position of being able to relate, from my own experiences and entirely without reference to books, when and how the changes occurred, how some of the actors felt and thought and acted in the presence of each new development, and what stupendous shifts in viewpoint have been brought about. This is my excuse for making this paper to some extent a personal narrative.

The transition from the old to the new mode of thought in physics was probably made as dramatically in my case as in that of anyone in the world, for I was in the fortunate position of having entered the field just three years before the end of the complete dominance of nineteenth-century modes of thought. In those three years I had the privilege of personally meeting and hearing lectures by the most outstanding creators of nineteeth-century physics—Kelvin, Helmholtz, Boltzman, Poincaré, Rayleigh, Van't Hoff, Michelson, Ostwald, Lorentz—every one of whom I met and heard between 1892 and 1896. In one of these lectures I listened with rapt attention to the expression of a point of view which was undoubtedly held by most of them—indeed by practically all physicists of that epoch; for it had been given expression more than once by the most distinguished men of the nineteenth century.

The speaker had reviewed, first the establishment and definite proof of the principles of mechanics during the seventeenth and eighteenth centuries culminating in La Place's great "Mecanique Celeste"; then he had turned to the wonderfully complete verification of the wave theory of light by Young, Fresnel, and others between 1800 and 1850, experiments which laid secure foundations for the later structure known as the physics of the ether, one of the most beau-

[1] This lecture (introductory paragraphs omitted) forms Part I of a volume entitled "Evolution in Science and Religion," by R. A. Millikan, published by the Yale University Press, copyright 1927; here reprinted by permission.

tiful products of nineteeth-century thinking and experimenting; then he had traced the development in the middle of the century of the greatest and most fundamental generalization of all science, the principle of the conservation of energy; then he had spoken of the establishment in the first two decades of the second half of the century of the second law of thermodynamics, the principle of entropy or of the degradation of energy, and finally of the development by Maxwell of the electromagnetic theory and its experimental verification by Hertz in 1888, only five years earlier than the date of the lecture. This theory abolished in all particulars except wave length the distinction between light and radiant heat and long electromagnetic waves, all these phenomena being included under the general head of the physics of the ether.

Then, summarizing this wonderfully complete, well-verified, and apparently all-inclusive set of laws and principles into which it seemed that all physical phenomena must forever fit, the speaker concluded that it was probable that all the great discoveries in physics had already been made and that future progress was to be looked for, not in bringing to light qualitatively new phenomena but rather in making more exact quantitative measurements upon old phenomena.

Just a little more than one year later and before I had ceased pondering over the aforementioned lecture, I was present in Berlin on Christmas eve, 1895, when Professor Röntgen presented to the German Physical Society his first X-ray photographs. Some of them were of the bones of his hand, others of coins and keys photographed through the opaque walls of a leather pocketbook, but all clearly demonstrating that he had found some strange new rays which had the amazing property of penetrating as opaque an object as the human body and revealing on a photographic plate the skeleton of a living person.

Here was a completely new phenomenon—a qualitatively new discovery and one having nothing to do with the principles of exact measurement. As I listened and as the world listened, we all began to see that the nineteenth century physicists had taken themselves a little too seriously, that we had not come quite as near sounding the depths of the universe, even in the matter of fundamental physical principles, as we thought we had.

This was the dramatic introduction, from the standpoint of one of the very young stage assistants in the play, to the new period in physics. Nobody at that time dreamed, however, what an amazing number of new phenomena would come to light within the next 30 years nor how revolutionary, or, better, how incomprehensible in terms of nineteenth century modes of thought some of them would be. But at any rate, Röntgen's discovery began to prepare the

mind for the startling changes that were to come. I shall catalogue some of the most significant of these changes under eight different heads, taking the discovery of X rays as the first.

Second. Röntgen's discovery furnished an instrument and a technique which made possible the rapid development of the electron theory of matter—one of the grandest, because the simplest, of all physical generalizations. Although this is in a sense the very heart and soul of the new physics, I shall pass over it here with only such mention as is necessary to give it a place in the catalogue of great new developments, because, superficially at least, the electron theory did not at first set itself in opposition to nineteenth-century points of view. It represented the discovery of a wonderful new world, the subatomic world of extraordinary simplicity and orderliness, but it left the world of large-scale phenomena, the old "macroscopic" world which we had known before, functioning pretty much in its nineteenth century fashion.

Third. Within a year of Röntgen's discovery, namely, in 1896, there came the discovery of radioactivity, and with that discovery, as soon as its significance began to be seen, man's view of the nature of this physical world changed overnight. Matter had theretofore been put up in a definite number—we knew not how many—of eternal, unchangeable chemical elements. In radioactivity we found two of these elements first spontaneously shooting off parts of themselves with speeds comparable with the speed of light—speeds which nobody had ever dreamed that matter in any form could under any circumstance attain—and second, by virtue of this process, transforming themselves into new elements; so that now we definitely know the life period of a considerable number of the erstwhile eternal elements.

The discovery of X rays in 1895 had revealed a whole domain of ether physics, of whose existence prior to 1895 we had been completely unconscious. The discovery of radioactivity in 1896 had revealed an entirely new property of matter and quite as important a property, so far as its influence upon our conceptions of our world are concerned, as any which had ever been discovered. For it forced us, for the first time, to begin to think in terms of a universe which is changing, living, growing, even in its elements—a dynamic instead of a static universe. It has exerted the most profound influence not only upon physics which gave it birth, but also upon chemistry, upon geology, upon biology, upon philosophy. Indeed, it is at this point that one of the great contributions of science to religion is now being made.

To the general public the wonder of radioactivity is now wearing off a bit merely because the phenomena have become familiar, but to the thoughtful observer the mystery is in some particulars as

great as on the day of its discovery. Whence, for example, does the energy come which enables a negative electron to disregard the enormous attraction of the positive nucleus for itself and eject itself with an energy of several million volts away from that nucleus? It is just as though a huge stone instead of remaining on the earth were sudenly to decide to shoot out into space with enormous velocity against the pull of gravity. Having set up the principle of the conservation of energy as our universal guide, philosopher, and friend, we physicists, of course, said that either the electron which had thus ejected itself from the nucleus must have suddenly absorbed the requisite energy from some unknown ether waves which are shooting through all space, or else it must have been already endowed with an enormous kinetic energy inside its infinitesimal nucleus, and some kind of entirely unknown trigger had acted to release this energy. The first hypothesis has already been weighed in the balance and found wanting, so that the second is, as we now suppose, all that is left. Thus we saved, after a fashion, our nineteenth century faces, though the seeking for any kind of mechanical model to carry the enormous subatomic energies released in the radioactive process seems so hopeless that it has ceased to be an interesting diversion in the kindergarten of the physicist. In a word, radioactivity not only revealed for the first time a world changing, transforming itself continually even in its chemical elements, but it began to show the futility of the mechanical pictures upon which we had set such store in the nineteenth century.

Fourth. It may have been something of a blow to the nineteenth century to learn of the general transmutability of the elements, but how much more of a shock to find that the principle of the conservation of matter itself is definitely invalid. Beginning in 1901 the mass of an electron was shown by direct experiment to grow measurably larger and larger as its speed is pushed closer and closer to the speed of light. But of much greater interest than that is the fact that Einstein worked out of the relativity formulae a general relation between the two quantities, energy and mass, of the form $mc^2=E$ in which m means mass in grams, c^2 is the velocity of light squared, or the enormous number 9×10^{20}, and E is energy in ergs. This equation seems now to have the best of experimental credentials. If it is a correct one, it means that matter itself in the Newtonian sense, the quantitative measure of which is mass or inertia, has entirely disappeared as a distinct and separate entity, as an invariant property of any system. In other words, matter may be annihilated, radiant energy appearing in its place; and in view of the enormous value of the factor 9×10^{20}, a very small number of grams of matter may transform themselves into a stupendous number of ergs of energy.

It is well known with what joy the astronomers have seized upon this fact to enable them to escape their otherwise insuperable difficulties encountered because the sun, for example, can not possibly have been pouring out heat as long as it is now known to have been doing, if it is merely a hot body cooling off. If, however, it has the capacity at the enormous temperatures existing in its interior, say 40,000,000° C., of transforming its very mass into radiant energy, then these particular difficulties disappear. But what a shock it would be to Lord Kelvin if he could hear the modern astronomers talking about the stars radiating away their masses through the mere act of giving off light and heat, and this is now orthodox astronomy.

And again, if they do so in accordance with the Einstein equation, then is it not more than probable that the process is also going on somewhere in the opposite sense and that radiant energy is condensing back into mass, that new worlds are thus continually forming as old ones are disappearing? These are merely the current speculations of modern physics, based, however, upon the now fairly definite discovery that conservation of matter in its nineteenth century sense is invalid.

Some time ago I was one of the speakers at a forum, and in the course of my address I used the word "spirit" a number of times. When questions were afterward called for, a man arose in the rear of the room and with a somewhat hostile air asked if the speaker would define what he meant by the word "spirit." I replied that if the interrogator would be good enough to define for me the word "matter" I would attempt to define for him the word "spirit." The attempt was not called for. And, in fact, in view of the growth of twentieth century physics and the changes in our conception of matter that it has brought, it is to-day quite as difficult to find a satisfactory definition of "matter" as of "spirit."

Fifth. But what do we now know about the nature of this phenomenon which we have called radiant energy, with the aid of which the masses of the stars are being dissipated into space? In a word, where is now the nineteeth century physics of the ether?

The physics of the ether meant in 1890 the physics of electromagnetic waves, and it means precisely that now. Electromagnetic waves are sharply and definitely recognizable by certain observed properties. Thus, in the first place, electromagnetic waves travel through space with an exactly measurable speed, namely, the speed of light, i. e., 186,000 miles per second. Second, they all exhibit a definite measurable periodicity, or frequency, which divided into the velocity of light, gives the wave length. Third, they all exhibit another measurable property described by the words "state of polarization," the precise definition of which need not here be given.

Note that these properties are completely independent of all theories as to the nature of electromagnetic waves.

We can produce and study electromagnetic waves of an infinite variety of frequencies ranging from very long wireless waves, kilometers long, up through heat waves to light waves of wave length of the order of $\frac{1}{10000}$ mm., up still farther through ultra-violet rays to X rays of frequencies 10,000 times that of ordinary light, and up again through gamma rays to the cosmic rays of frequencies again 1,000 times those of X rays. All this to show that the physics of the ether is not a vague set of ideas but that it deals with sharply measurable experimental facts, the validity of which is unquestioned, and which are completely independent of all speculations and theories.

Now, if in 1890 any physicist had been asked to describe the mode of interaction between ether waves, and, say, electrons in atoms, he would presumably have answered with great definiteness and assurance about as follows:

It is essentially the same as the mode of interaction between a tuning fork, or a piano string, and the air waves produced by its vibration. The fork sends out into the surrounding air a series of waves the period of which of course synchronizes with the period of the vibrating prong. If just such a series of waves should fall upon the fork when at rest it would pick up these waves and be set into vibration by them. But this would be true when, and only when, the frequency of the impressed or on-coming waves coincides with the natural frequency of the tuning fork. Precisely similarly the electrical charges—now called electrons—which are in the atoms of matter when these atoms are for example in the suns and stars, are set into all sorts of rapid vibrations and these vibrating electrical bodies impress their individual, or better their integrated, wave form upon the ether just exactly as the instruments of the orchestra impress their integrated wave form upon the air which transmits it to your ear.

Now up to 1900 all the phenomena of ether waves had seemed to fit accurately and beautifully into this sort of wave theory. Its succcesses were almost countless. It explained beautiful and intricate phenomena like the colors of soap bubbles and interference patterns of even the most complicated sort. Up to 1900, I say, the theory had never failed. But during the first 15 years of this century there was discovered a group of new phenomena which baffled explanation in terms of nineteenth century ether physics. These phenomena are as follows: When ether waves of sufficiently high frequency are allowed to fall upon the atoms of matter they are found to jerk the electrons from these atoms, and in so doing to communicate to them a kinetic energy which is independent of the intensity of the incident waves, but is accurately proportional to their frequency; i. e., kinetic energy imparted $=E=h\nu-p$ where h is a universal constant, ν the frequency of the incident waves, and p the work necessary to detach the electron from the metal. This is a phenomenon that has been checked in all sorts of ways and has always and

everywhere been verified, but it is one which is to the present day completely inexplicable in terms of the nineteenth century wave theory. It obviously fits better some sort of corpuscular theory than a wave theory. It is a new phenomenon of stupendous importance for the understanding of the foundations of the physical world in which we live.

Sixth. But now came, about 1913, the discovery of the effect inverse to the last. Not only was the energy communicated to an electron by an ether wave which was absorbed by that electron, proportional to the frequency of the wave, but when atoms of substances like glowing hydrogen, for example, emit ether waves, the frequency of the emitted light can be found by considering the electron in the act of emission to have fallen from one energy level E_1, to a second E_2 and to have emitted a frequency proportional to the change in energy, i. e., to E_1-E_2, the factor of proportionality being the same universal constant h; so that the equation $E_1=E_2-h\nu$ gives a reciprocal relation between the electronic energy and ether wave energy. This experimental discovery, first, that the frequency of an ether wave may be taken as a measure of its energy available for absorption by electrons, and second, that the energy $h\nu$ can interplay in this way between ether waves and electrons in atoms is so irreconcilable with the wave theory of the nineteenth century that Einstein has suggested abandoning the wave theory of light altogether and returning to a modified corpuscular theory of the transmission of radiant energy through space. Also at the hands of A. H. Compton this new light-dart theory has recently had new and striking success, but nobody has as yet been able to show how such a light-dart theory can account for the scores of interference phenomena so beautifully explained by the wave theory. Such is the impasse confronting physics to-day in its endeavor to obtain a picture of the mechanism of the transmission of radiant energy through space. We have discovered a whole group of new phenomena of radiation to which the old laws do not apply; yet we must retain the old laws for the interpretation of the old phenomena.

Seventh. Not only are we at present completely unable to form any consistent picture of the mechanism of the transmission of radiant energy, but new experiments have recently come to light which show conclusively that the frequency of an ether wave is not produced by, and does not correspond to, a synchronously vibrating electronic tuning fork within the atom at all. We can at present make no mechanical picture whatever of the act by which an ether wave is born and started out on its journey through space. Two electrons within the same atom have been definitely found in some instances to jump simultaneously each to a new position, and the sum of the energies of these two changes is somehow integrated by

the atom into a single monochromatic ether wave of a frequency corresponding to the sum of the two electron jumps. In a word, of the process by which an ether wave is born we know only this much, that every atomic shudder (change in energy) of whatever sort seems to become integrated into a monochromatic ether wave, the frequency of which is computable from $h\nu = E_1 - E_2$, E_1 being the atomic energy before the shudder and E_2 that after it, so far have we got from the simple mechanical picture of a little electrical vibrating tuning fork sending off waves into the ether synchronously with its own vibration. Both the mode of birth of an ether wave by an atom and its mode of transmission from star to star after birth are still almost complete mysteries.

I shall mention but one more of the large category of discoveries constituting twentieth century physics. It is perhaps the most striking and revolutionary of them all. The discovery that the very foundations of mechanics when looked at microscopically are unsound, that apparently all periodic motions are resolvable into circular and linear coordinates which can not progress continuously as demanded by the Newtonian laws, but are built up out of definite unitary elements; specifically, that a body rotating in a circle can possess only such angular momenta as are exact multiples of a universal unit of angular momentum, viz, $\frac{h}{2\pi}$. This unitary fine structure in motion, like the unitary fine structure in electricity, we had never discovered nor even dreamed of until this century, because we had never experimented upon small enough angular momenta on the one hand, electrostatic charges on the other, to see that each had in fact a granular structure. When one is weighing sand by the ton it has for him no granular character. It is only when he begins to weigh quantities of the size of individual grains that he sees it to be granular. That periodic motion itself has such a granular nature is one of the most amazing experimental discoveries of our century. We can still look with a sense of wonder and mystery and reverence upon the fundamental elements of the physical world as they have been partially revealed to us in this century. The childish mechanical conceptions of the nineteenth century are now grotesquely inadequate.

We have now no one consistent scheme of interpretation of physical phenomena and we have become wise enough to see and to admit that we have none. We use the wave theory, for example, where it works; we use the quantum theory where it works, and we try to bridge the gap between the two apparently contradictory theories in purely formal fashion by what we call the correspondence principle. It is true that we are slowly learning more of the rules in

nature's game, so that our progress is not made by hit or miss experimenting or by random theorizing, but by following a more or less systematic, if not always a strictly logical procedure; but the day has gone by when any physicist thinks that he understands the foundations of the physical universe as we thought we understood them in the nineteenth century. The foregoing discoveries of our generation have taught us a wholesome lesson of humility, wonder, and joy in the face of an as yet incomprehensible physical universe. We have learned not to take ourselves as seriously as the nineteenth century physicists took themselves. We have learned to work with new satisfaction, new hope and new enthusiasm because there is still so much that we do not understand, and because, instead of having it all pigeonholed as they thought they had, we have found in our lifetimes more new relations in physics than had come to light in all preceding ages put together, and because the stream of discovery as yet shows no signs of abatement.

ISAAC NEWTON[1]

By Albert Einstein

The two-hundredth anniversary of the death of Newton falls at this time. One's thoughts can not but turn to this shining spirit, who pointed out, as none before or after him did, the path of Western thought and research and practical construction. He was not only an inventor of genius in respect of particular guiding methods; he also showed a unique mastery of the empirical material known in his time, and he was marvelously inventive in special mathematical and physical demonstrations. For all these reasons he deserves our deep veneration. He is, however, a yet more significant figure than his own mastery makes him, since he was placed by fate at a turning point in the world's intellectual development. This is brought home vividly to us when we recall that before Newton there was no comprehensive system of physical causality which could in any way render the deeper characters of the world of concrete experience.

The great materialists of ancient Greek civilization had indeed postulated the reference of all material phenomena to a process of atomic movements controlled by rigid laws, without appealing to the will of living creatures as an independent cause. Descartes, in his own fashion, had revived this ultimate conception. But it remained a bold postulate, the problematic ideal of a school of philosophy. In the way of actual justification of our confidence in the existence of an entirely physical causality, virtually nothing had been achieved before Newton.

NEWTON'S AIM

Newton's aim was to find an answer to the question: Does there exist a simple rule by which the motion of the heavenly bodies of our planetary system can be completely calculated, if the state of motion of all these bodies at a single moment is known? Kepler's empirical laws of the motion of the planets, based on Tycho Brahe's observations, were already enunciated, and demanded an interpreta-

[1] Reprinted by permission from the Manchester Guardian of March 19, 1927. (Copyright in the United States of America.)

tion.[2] These laws gave a complete answer to the question how the planets moved round the sun (elliptical orbit, equal areas described by the radius vector in equal periods, relation between semi-major axis and period of revolution). But these rules do not satisfy the requirement of causality. The three rules are logically independent of one another, and show no sign of any interconnection. The third law can not be extended numerically as its stands, from the sun to another central body; there is, for instance, no relation between a planet's period of revolution round the sun and the period of revolution of a moon round its planet.

But the principal thing is that these laws have reference to motion as a whole, and not to the question how there is developed from one condition of motion of a system that which immediately follows it in time. They are, in our phraseology of to-day, integral laws, and not differential laws.

The differential law is the form which alone entirely satisfies the modern physicist's requirement of causality. The clear conception of the differential law is one of the greatest of Newton's intellectual achievements. What was needed was not only the idea but a formal mathematical method which was, indeed, extant in rudiment but had still to gain a systematic shape. This also Newton found in the differential and integral calculus. It is unnecessary to consider whether Leibnitz arrived at these same mathematical methods independently of Newton or not; in any case, their development was a necessity for Newton, as they were required in order to give Newton the means of expressing his thought.

THE STEP FROM GALILEO TO NEWTON

Galileo had already made a significant first step in the recognition of the law of motion. He discovered the law of inertia and the law of free falling in the earth's field of gravitation: A mass (or, more accurately, a material point) uninfluenced by other masses moves uniformily in a straight line; the vertical velocity of a free body increases in the field of gravity in proportion to the time. It may seem to us to-day to be only a small step from Galileo's observations to Newton's laws of motion. But it has to be observed that the two propositions above, in the form in which they are given, relate to motion as a whole, while Newton's law of motion gives an answer to the question: How does the condition of motion of a point-mass change in an infinitely small period under the influence of an external force? Only after proceeding to consider the phenomenon during an

[2] Everyone knows to-day what gigantic efforts were needed to discover these laws from the empirically ascertained orbits of the planets. But few reflect on the genius of the method by which Kepler ascertained the true orbits from the apparent ones; i. e., their directions as observed from the earth.

infinitely short period (differential law) does Newton arrive at a formula which is applicable to all motions. He takes the conception of force from the already highly developed theory of statics. He is only able to connect force with acceleration by introducing the new conception of mass, which, indeed, is supported curiously enough by an apparent definition. To-day we are so accustomed to forming conceptions which correspond to differential quotients that we can hardly realize any longer how great a capacity for abstraction was needed to pass across a double barrier to the general differential laws of motion, with the further need to evolve the conception of mass.

But this was still a long way from the causal comprehension of the phenomena of motion. For the motion was only determined by the equation of motion if the force was given. Newton had the idea, to which he was probably led by the laws of the planetary motions, that the force acting on a mass is determined by the position of all masses at a sufficiently small distance from the mass in question. Not until this connection was realized was a completely causal comprehension of the phenomena of motion obtained. How Newton, proceeding from Kepler's laws of the motion of planets, solved this problem for gravitation and so discovered the identity of the nature of gravity with the motive forces acting on the stars is common knowledge. It is only the combination of—

(Law of motion) + (Law of attraction)

through which is constituted that wonderful thought-structure which enables the earlier and later conditions of a system to be calculated from the conditions ruling at one particular time, in so far as the phenomena occur under the sole influence of the forces of gravitation. The logical completeness of Newton's system of ideas lay in the fact that the sole causes of the acceleration of the masses of a system prove to be the masses themselves.

On the basis sketched Newton succeeded in explaining the motions of the planets, moons, comets, down to fine details, as well as the ebb and flow of the tides and the precessional movement of the earth—this last a deductive achievement of peculiar brilliance. It was, no doubt, especially impressive to learn that the cause of the movements of the heavenly bodies is identical with the force of gravity, so familiar to us from everyday experience.

SIGNIFICANCE OF NEWTON'S ACHIEVEMENT

The significance, however, of Newton's achievement lay not only in its provision of a serviceable and logically satisfactory basis for mechanics proper; up to the end of the nineteenth century it formed the program of all theoretical physical research. All physical phe-

nomena were to be referred to masses subject to Newton's law of motion. Only the law of force had to be amplified and adapted to the type of phenomena which was being considered. Newton himself tried to apply this program in optics, on the hypothesis that light consisted of inert corpuscles. The optics of the undulatory theory also made use of Newton's law of motion, the law being applied to continuously diffused masses. The kinetic theory of heat rested solely on Newton's formulæ of motion; and this theory not only prepared people's minds for the recognition of the law of the conservation of energy, but also supplied a theory of gases confirmed in its smallest details, and a deepened conception of the nature of the second law of thermodynamics. The theory of electricity and magnetism also developed down to modern times entirely under the guidance of Newton's basic ideas (electric and magnetic substance, forces at a distance). Even Faraday and Maxwell's revolution in electro-dynamics and optics, which was the first great advance in the fundamental principles of theoretical physics since Newton, was still achieved entirely under the guidance of Newton's ideas. Maxwell, Boltzmann, and Lord Kelvin never tired of trying again and again to reduce electromagnetic fields and their dynamical reciprocal action to mechanical processes occurring in continuously distributed hypothetical masses. But owing to the barrenness, or at least unfruitfulness, of these efforts there gradually occurred, after the end of the nineteenth century, a revulsion in fundamental conceptions; theoretical physics outgrew Newton's framework, which had for nearly two centuries provided fixity and intellectual guidance for science.

NEWTON ON ITS LIMITATIONS

Newton's basic principles were so satisfying from a logical standpoint that the impulse to fresh departures could only come from the pressure of the facts of experience. Before I enter into this I must emphasize that Newton himself was better aware of the weak sides of his thought-structure than the succeeding generations of students. This fact has always excited my reverent admiration; I should like, therefore, to dwell a little on it.

1. Although everyone has remarked how Newton strove to represent his thought-system as necessarily subject to the confirmation of experience, and to introduce the minimum of conceptions not directly referable to matters of experience, he makes use of the conceptions of absolute space and absolute time. In our own day he has often been criticized for this. But it is in this very point that Newton is particularly consistent. He had recognized that the observable geometrical magnitudes (distances of material points from one another) and their change in process of time do not completely deter-

mine movements in a physical sense. He shows this in the famous bucket experiment. There is, therefore, in addition to masses and their distances, varying with time, something else, which determines what happens; this "something" he conceives as the relation to "absolute space." He recognizes that space must possess a sort of physical reality if his laws of motion are to have a meaning, a reality of the same sort as the material points and their distances.

This clear recognition shows both Newton's wisdom and a weak side of his theory. For a logical construction of the theory would certainly be more satisfactory without this shadowy conception; only those objects (point-masses, distances) would then come into the laws whose relation to our perceptions is perfectly clear.

2. The introduction of direct, instantaneously acting forces at a distance into the exposition of the effects of gravitation does not correspond to the character of most of the phenomena which are familiar to us in our daily experience. Newton meets this objection by pointing out that his law of reciprocal gravitation is not to be taken as an ultimate explanation, but as a rule induced from experience.

3. Newton's theory offered no explanation of the very remarkable fact that the weight and inertia of a body are determined by the same magnitude (the mass). The remarkable nature of this fact struck Newton also.

None of these three points can rank as a logical objection against the theory. They form, as it were, merely unsatisfied needs of the scientific spirit in its effort to penetrate the processes of nature by a complete and unified set of ideas.

THE THEORY OF THE ELECTROMAGNETIC FIELD

Newton's theory of motion, considered as a program for the whole field of theoretical physics, suffered its first shock from Maxwell's theory of electricity. It was found that the reciprocal action between bodies through electrical and magnetic bodies does not take place through instantaneously acting forces at a distance, but through processes which are transmitted with finite velocity through space. Alongside the point-mass and its movements there arose, in Faraday's conception, a new sort of physically real thing, the "field." It was first sought to conceive this, with the aid of mechanical modes of thought, as a mechanical condition (of movement or strain) of a hypothetical space-filling medium (the ether). When, however, in spite of the most obstinate efforts, this mechanical interpretation refused to work, students slowly accustomed themselves to the conception of the "electromagnetic field" as the ultimate irreducible foundation stone of physical reality. We owe to H. Hertz the deliberate liberation of the conception of the field from all

the scaffolding of the conceptions of mechanics, and to H. A. Lorentz the liberation of the conception of the field from a material bearer; according to Lorentz the physical empty space (or ether) alone figured as bearer of the field; in Newton's mechanics, indeed, space had not been devoid of all physical functions. When this development had been completed, no one any longer believed in directly acting instantaneous forces at a distance, even in connection with gravitation, though a field theory for gravitation, for lack of sufficient known facts, was not unmistakably indicated. The development of the theory of the electromagnetic field also led, after Newton's hypothesis of action at a distance had been abandoned, to the attempt to find an electromagnetic explanation for Newton's law of motion, or to replace that law by a more accurate law based on the field theory. These efforts were not crowned with full success, but the mechanical basic conceptions ceased to be regarded as foundation stones of the physical conception of the universe.

The Maxwell-Lorentz theory led inevitably to the special theory of relativity, which, by destroying the conception of absolute simultaneity, negatived the existence of forces at a distance. Under this theory mass is not an unalterable magnitude, but a magnitude dependent on (and, indeed, identical with) the amount of energy. The theory also showed that Newton's law of motion can only be considered as a limiting law valid only for small velocities, and substituted for it a new law of motion, in which the velocity of light in a vacuum appears as the limiting velocity.

THE GENERAL THEORY OF RELATIVITY

The last step in the development of the program of the field theory was the general theory of relativity. Quantitatively it made little modification in Newton's theory, but qualitatively a deep-seated one. Inertia, gravitation, and the metrical behavior of bodies and clocks were reduced to the single quality of a field, and this field in turn was made dependent on the bodies (generalization of Newton's law of gravitation or of the corresponding field law, as formulated by Poisson). Space and time were so divested, not of their reality, but of their causal absoluteness (absoluteness—influencing, that is, not influenced), which Newton was compelled to attribute to them in order to be able to give expression to the laws then known. The generalized law of inertia takes over the *rôle* of Newton's law of motion. From this short characterization it will be clear how the elements of Newton's theory passed over into the general theory of relativity, the three defects above mentioned being at the same time overcome. It appears that within the framework of the general theory of relativity the law of motion can be deduced from the law

of the field, which corresponds to Newton's law of force. Only when this aim has been fully attained can we speak of a pure theory of fields.

Newton's mechanics prepared the way for the theory of fields in a yet more formal sense. The application of Newton's mechanics to continously distributed masses led necessarily to the discovery and application of partial differential equations, which in turn supplied the language in which alone the laws of the theory of fields could be expressed. In this formal connection also Newton's conception of the differential law forms the first decisive step to the subsequent development.

The whole development of our ideas concerning natural phenomena, which has been described above, may be conceived as an organic development of Newton's thought. But while the construction of the theory of fields was still actively in progress, the facts of heat radiation, spectra, radioactivity, and so on, revealed a limit to the employment of the whole system of thought, which, in spite of gigantic successes in detail, seems to us to-day completely insurmountable. Many physicists maintain, not without weighty arguments, that in face of these facts not only the differential law but the law of causality itself—hitherto the ultimate basic postulate of all natural science—fails.

The very possibility of a spatio-temporal construction which can be clearly brought into consonance with physical experience is denied. That a mechanical system should permanently admit only discrete values of energy or discrete states—as experience, so to say, directly shows—seems at first hardly deducible from a theory of fields working with differential equations. The method of De Broglie and Schrödinger, which has, in a certain sense, the character of a theory of fields, does deduce, on the basis of differential equations, from a sort of considerations of resonance the existence of purely discrete states and their transition into one another in amazing agreement with the facts of experience; but is has to dispense with a localization of the mass-particles and with strictly causal laws. Who would be so venturesome as to decide to-day the question whether causal law and differential law, these ultimate premises of Newton's treatment of nature must definitely be abondoned?

THE NUCLEUS OF THE ATOM [1]

By J. A. Crowther
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Since Rutherford in 1911 first propounded his nuclear theory of the atom, the evidence which has been accumulated from many and varied phenomena has been so weighty, and so consistently in favor of his suggestions that there is now a very general agreement among physicists that the nuclear hypothesis embodies the essential truth about atomic structure. The atom of any substance is now regarded as being made up of a central core, or nucleus, of almost incredibly small dimensions (in which, nevertheless, practically the whole of the mass of the atom resides), surrounded by a swarm of negative electrons. The nucleus, as a whole, is positively charged and under its attractive force the negative electrons describe around it circular or elliptical orbits, in much the same way as the planets circulate around the sun. Since the normal atom is electrically neutral, the resultant positive charge on the nucleus is equal to the sum of the charges on the planetary electrons. If we take the charge on a negative electron as our unit of charge we may say that the positive charge on the nucleus of an atom is numerically equal to the number of planetary electrons it contains.

The problem of atomic structure thus divides into two parts—the determination of the arrangement of the planetary electrons, and the structure of the central nucleus. The first of these problems has been attempted, with remarkable success by Niels Bohr, and the general outlines of his solution are well known to most readers. The second problem is now being attacked by Sir Ernest Rutherford and his pupils. In many ways it is the more difficult problem of the two. The motions of the planetary electrons are responsible for the optical and X-ray spectra of the atom; while their arrangement determines its chemical and physical properties. There is thus a wealth of experimental data to guide the adventurer in this realm. The nucleus, on the other hand, is a world remote and inaccessible. It is true that its charge determines and controls the electronic orbits, but at the distances at which these electrons revolve the evidence shows that the nucleus acts merely as a point charge, and reveals nothing of its structure. The only properties definitely assignable to the nucleus are mass, and, where the element is radioactive, radioactivity. These

[1] Reprinted by permission of the Editor, Prof. E. Rignano, from Scientia, International Review of Scientific Synthesis, vol. XXXIX, No. CLXVII–3, Mar. 1, 1926. Publishers, G. E. Stechert and Co., New York.

are our only guides to a study of atomic nuclei. These simple means in the hands of Sir Ernest Rutherford have already sufficed to give much information about these minute, but important structures.

Most of us have, at some time or other, discovered the presence of a chair in a pitch dark room by the simple process of colliding with it. This is essentially the method developed by Sir Ernest Rutherford for his investigations of the nucleus. High-speed projectiles of suitably small dimensions are fired through matter and from the number and magnitude of the deflections which they undergo, inferences are drawn as to the number and nature of the obstacles which they have met. Suitable projectiles for the purpose are found in the α particles from radioactive substances. The α particle is an atom of helium which has lost two electrons, and thus carries a double positive charge. But it is known from the work of Mosely on X-ray spectra that the number of planetary electrons contained in the atom of a given element is equal to the atomic or ordinal number of the element. Since helium is No. 2 in the order of the elements it has, normally, two planetary electrons only. Hence the α particle is the nucleus of the helium atom, stripped of its planetary electrons.

If a parallel beam of such particles is projected through a thin sheet of matter the majority of the particles emerge without appreciable deviation. A small fraction are, however, deflected through considerable angles, occasionally through more than a right angle. It was this observation which originated, and indeed necessitates, a nuclear theory of the atom. A particle of the mass and speed of an α particle can only be deviated through a sensible angle when it collides with an obstacle of mass comparable with or greater than its own. The experiments showed that this was a comparatively rare occurrence. But in passing through the thinnest sheet of gold leaf the α particle must pass through at least a hundred atoms of gold. The atom, as such, is, therefore, not a structure which can deflect an α particle. On the other hand, particles capable of producing large deflections do exist in the material. We are driven to the conclusion that the mass of the atom is not distributed uniformly through its bulk but is concentrated in a particle whose dimensions are much smaller than that of the atom, in other words in a nucleus.

A more detailed study of the deflections undergone by the deflected α particles enables us to estimate with fair accuracy the dimensions of the nucleus. The majority of the collisions studied are not of the nature of the collisions between, say, two billiard balls, where one particle actually impinges on the other, though collisions of this type have been observed. The α particle and the atomic nucleus are each positively charged and thus repel each other with a force varying as the inverse square of the distance. The deviation in most

cases is due to this electrostatic repulsion, and the "collision" between the particles thus resembles the sweep of a comet through the solar system; the only difference being that the α particle is repelled, while the comet is attracted, by the central sun. The solution of the problem is fully worked out in books on Dynamics, and its extension to the case of the scattering of a beam of α particles is quite simple. It can thus be shown that, assuming the deflections to be caused by an electrostatic force varying inversely as the square of the distance, the fraction of the whole number of particles scattered through an angle greater than ϕ by a sheet of matter of thickness t is $\pi\, nt \frac{N^2e^4}{4T^2} \cot^2 \frac{\Phi}{2}$ where n is the number of atoms per c. c. in the material, N the atomic number, and T the kinetic energy of the α particle; e being, as usual, the unit electronic charge. All these quantities are well known. The theory has been tested with great accuracy by Chadwick, using sheets of copper, silver, and gold, and the measured deflections were found to agree with those calculated from the formula to an accuracy of at least one per cent. The α particle and the nuclei of copper, silver, and gold thus act like point charges repelling each other in accordance with the law of inverse squares at least up to the minimum distance of approach of the α particle to the nuclei in these experiments. This minimum distance was found, by calculation, to be of the order of 5×10^{-12} cm. Since the inverse square law could certainly not apply if the particles came into actual contact, the radii of the nuclei must certainly be smaller than this distance, which gives us, therefore, an upper limit to the size of the nucleus. The radius of an atomic nucleus is, therefore, certainly less than one two thousandth of that of the atom.

The matter can, however, be pushed a little further. The force between an α particle and a nucleus will be smaller as the charge on the nucleus becomes smaller, that is to say as the atomic number of the atom becomes less. Thus the smaller the atomic number of the scattering element, the nearer will the α particle be able to approach its nucleus. The minimum distance of approach also becomes smaller as the velocity of the α particle increases. Hence by using scattering substances of low atomic number and high speed α particles we can get closer and closer to the mysterious world we are investigating. Some experiments, made originally by Rutherford and extended by Chadwick and Bieler, on the scattering of α particles by hydrogen are of peculiar interest in this connection.

The problem becomes a little more complex when the α particle is being scattered by a gas the particles of which are themselves free to remove, but an exact solution can be obtained, on the same assumptions as to the nature of the collisions as were made in the previous case. The hydrogen nuclei should be scattered in all directions, by the force of the impact, in numbers and with velocities

which can easily be calculated. Using α particles of comparatively small velocity these calculations were actually verified. When, however, the experiments were repeated using the fastest α particles available, those emitted by Radium C, the agreement between the experimental observations and the theory completely broke down. The hydrogen nuclei instead of being scattered in all directions as required by the simple theory were found to be projected mainly in the direction of the oncoming α particles, and the number set in motion was also greater than was to be expected. At the very close distances of approach reached in these experiments (about 4×10^{-13} cm.) the inverse square law of force completely fails to describe the phenomena, and the particles no longer act like point charges; in other words they are revealed as structures with an extension in space which now has to be taken into account.

The observed direction of projection of the hydrogen nuclei would be obtained if the projectiles, instead of being spherical, were flattened disks. A number of flat disks traveling face forward through a cloud of pellets would project all the pellets with which they came into contact in a direction identical with that in which they themselves were traveling. The parallelism of the projected hydrogen nuclei is not quite so extreme as would be observed if the colliding particles were actually flat. Chadwick and Bieler were able to show that the actual distribution of directions among the hydrogen particles was just what would be obtained if the α particles behaved like perfectly elastic spheroids having major and minor axes of 8×10^{-13} cm. and 4×10^{-13} cm., respectively. It is, of course, more than improbable that this rather crude picture represents the actual α particle, or helium nucleus. What we can assert, however, is that outside this spheroid the helium nucleus behaves approximately as a single point charge, while inside the spheroid the repulsive forces increase so rapidly that the hydrogen nuclei are driven from it, as if from a highly elastic and rigid surface. At such distances then we are approaching the actual structure of the helium nucleus itself.

These calculations were made on the assumption that the dimensions of the hydrogen nucleus, the other partner to the collision, were negligibly small in comparison with those of the α particle. There is much fairly strong, though indirect evidence, for this assumption. Aston's important measurements with the mass spectrograph have shown that every atom has a mass which is represented, almost exactly, by a whole number if the mass of the oxygen atom is taken as 16. The most reasonable explanation of this remarkable fact is that every nucleus is built up of a whole number of particles each of mass equal to unity on this scale, and presumably, therefore, hydrogen nuclei. It is true that the mass of a hydrogen nucleus, on this scale, is somewhat greater than unity, 1.0077, but modern electrical

theory would lead us to expect that the mass of the hydrogen nucleus would be somewhat less when it was closely packed together with other similar particles than when in an isolated state. It is generally held at present that the hydrogen nucleus is the positive counterpart of the negative electron; the second of the two fundamental units from which all matter is built. For this reason Sir Ernest Rutherford proposes to call it a proton. The mass of any atom would thus be that of the protons contained in its nucleus. The uranium nucleus must therefore contain about 238 protons, inclosed in a volume whose radius is certainly not more than 6×10^{-12} cm. The proton is clearly then a very minute particle.

Assuming that Aston's experiments indicate that every atomic nucleus is built up of an integral number of protons, we can easily determine the constituents of any given nucleus. The mass of the nucleus, that is to all intents and purposes the mass of the atom, tells us the number of protons contained in the nucleus; the atomic number of the element gives us, as we have already seen, the resultant positive charge. Except in the case of hydrogen the atomic number is less than the atomic weight. Consequently part of the charge on the protons must be neutralized by a negative charge, presumably supplied by an appropriate number of negative electrons. The helium nucleus, for example has a mass of four, and must, therefore, contain four protons. Its nuclear charge is, however, two, and consequently, since the charge on the proton is numerically equal to that on an electron, the helium nucleus must also contain two negative electrons. It is interesting to notice that, since an electron has a diameter of about 4×10^{-13} cm., and the volume of the proton is negligible, this structure would have dimensions agreeing quite closely with those suggested by Chadwick and Bieler. The presence of negative electrons in the nuclei of the radioactive elements is proved by their β ray activity. The majority of the high speed electrons making up the β radiation undoubtedly come from the disintegrating nucleus. The presence of negative electrons in the nuclei of the lighter elements is, therefore, not surprising.

It will be seen that on these suppositions a nucleus with a given nuclear charge can be built up in many different ways. Thus the lithium nucleus, with a resultant charge of three, might equally well consist of six protons and three electrons, or of seven protons and four electrons. Since the chemical and physical properties of an element depend only on the arrangement of the planetary electrons, which in turn depends only on the resultant nuclear charge, both the nuclei would give rise to atoms possessing the same properties. Both kinds of atoms, the first with an atomic mass six, the second with atomic mass seven, have been observed by Aston in lithium. The

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phenomena is known as isotopy, and is obviously explained on the theory of the nucleus propounded above. The difficulty is, in fact, to explain why the number of isotopes is so few. The explanation will no doubt be forthcoming when more is known of the laws governing the nuclear structure.

It is clear from these facts that the nucleus of an element of high atomic weight is a complex structure containing many particles. Assuming the atomic weight of uranium to be 238 and its atomic number 92, its nucleus must contain 238 protons and 146 electrons condensed in a volume the radius of which is no more than 6×10^{-12} cm. The question naturally arises what is the "cement" which holds together this swarm of highly electrified particles in so small a space and how are they arranged in it? To these questions we have at present only the beginning of an answer. Some quite recent experiments of Bieler have shown that in very close proximity to the nucleus new and unexpected forces are apparently brought into play. We have seen that the α particles are able to penetrate much nearer to the nuclei of elements of low than of high atomic number. Experiments on the scattering of α particles, similar to those by which Chadwick was enabled to verify the inverse square law of force, were carried out with scattering materials of much lower atomic number. It was found that the deflections of the α particles in such substances were distinctly less than the theoretical values. With aluminum as the scattering substance, the difference amounted to nearly 7 per cent, even with the more slowly moving α particles, and increased to as much as 29 per cent with the fastest rays, which, of course, approach the nuclei more nearly.

It seems clear that at the very small distances reached in these encounters the inverse square law is no longer sufficient to account for the observed phenomena. Either the law of force between two electrical charges changes when their distance apart is very minute or some new force is called into play which falls off with increasing distance so much more rapidly than the ordinary electrical force that it becomes inappreciably small at finite distances. Bieler found that his results could best be explained by assuming the existence of an attractive force between the nucleus and the α particle, varying inversely as the fourth power of the distance between them. This attractive force would exactly balance the electrostatic repulsion between the nuclear charges at a distance, which was calculated to be 3.4×10^{-13} cm. from the center of the aluminum nucleus. Outside this distance the force between the colliding particles was entirely repulsive; inside this distance it would be entirely attractive. A positive particle which succeeded in penetrating within this charmed circle would thus fall into the nucleus.

That the law of force between two complex structures like atomic nuclei when brought very close together can be adequately repre-

sented by so simple a law of force is somewhat improbable. That the force should change from one of repulsion to one of attraction seems to be necessitated by the very existence of a nucleus. It is, moreover, corroborated by some very recent experiments by Rutherford. An α particle approaching an aluminum nucleus will be repelled, and will, therefore, be spending its energy until the critical circle is reached. Once this point is passed it will fall spontaneously into the nucleus, gathering fresh energy as it goes. We can, indeed, regard this critical circle as a high mountain ridge surrounding a small, deep, circular valley in which the nucleus lies. In electrical language the circle is one of maximum potential. Now, suppose we fire an α particle up this rising slope. If its initial energy is insufficient to carry it to the top, it will come momentarily to rest and then roll back again down the slope. If, however, it has enough or more than enough energy to carry it over the ridge, it will fall into the valley beyond; that is, into the nucleus. What happens under these circumstances was already known from earlier experiments. The aluminum nucleus is disintegrated and one or more protons, or hydrogen nuclei, are ejected from it. A similar artificial disintegration can be produced by the same means in other elements of low atomic weight. The minimum energy which an α particle must have to produce this disintegration must obviously be sufficient to carry it over the crest of the potential slope. Direct measurements showed that the disintegration of aluminum was not effected unless the α particles used had an initial energy corresponding to that which they would acquire in falling freely through a potential difference of 2,800,000 volts. Neglecting any trifling losses of energy which the α particle may undergo in its path due to other causes, the height of our mountain ridge must therefore be about 2,800,000 volts in electrical units.

The matter can also be tested from the other side. The proton expelled must have come from the valley over the ridge, and, even if it topped the ridge with no remaining velocity, its final velocity on leaving the atom must be at least that which would be produced by a free fall down the outer electrical slope, since in this part of its journey it is being vigorously repelled by the nucleus it has left. The hydrogen particles will thus be expelled with a minimum energy corresponding to that gathered during a free fall through the full potential of the critical layer. By actual measurement Rutherford found that the minimum energy with which the particles were expelled corresponded to a fall through about 3,000,000 volts. The very close agreement of the two estimates affords the strongest evidence for the actual existence of a surface of maximum potential surrounding the nucleus, and for the change in direction of the force at this point from which it was deduced.

The problem of the arrangement of the protons and electrons within the atomic nuclei is still unsolved, but evidence is rapidly accumulating which should ultimately provide a solution when we have discovered how to deal with it. Some information is provided by experiments on the disintegration of the nucleus. It is interesting to notice, for example, that in radioactive disintegrations the particles ejected are invariably either helium nuclei, forming the α rays, or electrons forming the β rays. On the other hand, the particles ejected during the artificial disintegrations studied by Rutherford seem to be invariably protons. The most probable suggestion at the moment is that the protons and electrons in the nucleus tend to combine to form very stable helium nuclei. Some, however, either because they are present in insufficient number to build up the helium structure, or for other reasons at present unknown, are in a comparatively free state, and are thus more readily dislodged by shocks from without. This view is supported by the fact that all efforts to disintegrate the atoms of carbon and oxygen, whose atomic masses are exact integral multiples of that of helium, have so far failed, though other elements of neighboring atomic mass are disintegrated with ease.

It is also possible to conceive of the nucleus of an element of high atomic number as possessing a solid core of protons and electrons, arranged in some kind of space lattice much as the atoms of sodium and chlorine are arranged in a crystal of rock salt, while other electrons and protons, not yet combinable into the structure of this central core, circulate around it in a series of nuclear orbits. Exact and delicate measurements recently made by Ellis, and by Meitner, on the γ ray spectra of the radioactive elements have shown fairly conclusively that Bohr's theory of X-ray spectra which has been applied with so much success to elucidating the arrangement of the planetary electrons in the atom, can be extended to the characteristic γ ray spectra of these radioactive elements. The emission of γ radiation is, however, a function of the nucleus. Even within the nucleus, then, it appears that we have "quantum" orbits, associated with definite energy levels, corresponding, though governed perhaps by other laws, to the electron orbits and levels in the outer part of the atom. Experiments, to the degree of accuracy required, are difficult and the results are not always easy to interpret without ambiguity. We may reasonably hope, however, that before long the nucleus, inconceivably minute as is its size, will yield up its secrets under the mass attack which is now being launched against it, with results as fascinating and as important as those obtained in the investigation of the structure of the outer parts of the atom.

PORTRAIT OF AUGUSTIN FRESNEL (AFTER A PICTURE BY TARDIEU)

THE CENTENARY OF AUGUSTIN FRESNEL[1]

By E.-M. Antoniadi

[With 1 plate]

This illustrious man is the dominant figure in optics. The success of his attacks upon the problems connected with light has been without equal. He succeeded where Newton failed and made clear the mysterious nature of light.

Augustin-Jean Fresnel was born at Broglie, in the Province of Normandy (Eure), on May 10, 1788. As a child he gave signs of his predilection for the sciences, and at the age of 16 he entered the École Polytechnique, in Paris, later finishing his training as an engineer at the Ponts et Chaussées. In 1815, upon the return of the Emperor from the island of Elba, he declared his allegiance to the Bourbons, passing the "one hundred days" in a quiet retreat in scientific meditation.

Before considering the scientific work of Fresnel we should examine the optical theories prevalent when he entered the field. Empedocles in ancient times was the first to conceive the idea that the propagation of light was not instantaneous, a fact which Roemer demonstrated in masterly fashion at the Observatory of Paris in 1675. Twenty-four centuries ago Democritus, the founder of the atomic theory, considering the very essence of light, attributed it to very tenuous particles shot out from the luminous body. This was the origin of the emission theory adopted by Newton in the seventeenth century, following his celebrated experiment upon the decomposition of light in passing through a prism. Already, however, Leonardo da Vinci, in the fifteenth century, and subsequently Malebranche and Hooke, of the time of Newton, had had a glimpse of the undulatory nature of light. Huyghens further developed this idea and studied the course of light rays through birefringent crystals. He developed his famous law, and as a medium in which the rays of light might be propagated brought out the idea of the ether, an ideal substance, so to speak, of extreme rarefaction and with which the ancients believed the whole universe to be filled.[2]

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[1] Translated by permission from L'Astronomie, Paris, June. 1927.

[2] That is the ἄπειρος αἰθήρ, the infinite ether of Heraclides of Pontus and of the Pythagoreans, the real discoverers of the heliocentric system of the universe 2,000 years before Copernicus (Stobée, Physics I, 24).

Euler was following in the path of Huyghens when Newton, entering the scene, objected that, if light were due to waves, the latter would invade the space behind a body, thus making shadows impossible. This, however, proved to be a double-edged weapon, for, while reducing his opponents to silence, Newton himself could not escape from the consequences of his own arguments and he had to explain very artificially, by added suppositions, the rings shown by thin lamina just discovered by him. Newton was not in optics the transcendent man that he was in the universal attraction due to gravity. He had stated a definite dislike of hypotheses but no man was more prone to use them; starting from false premises, he piled error upon error. His emission theory has died, never to return.

This state of affairs continued up to the beginning of the nineteenth century, when Thomas Young, the most gifted of English scientists since Newton, in his turn took up the undulatory theory of light. After starting his career with the excellent discovery that the accommodation of the eye was produced by changes in the curvature of its crystalline lens, with rare sagacity he showed that the principle of interference already utilized with sound was applicable to light. He thus explained the rainbow tints of thin lamina and Newton's rings and subsequently the colors of striated surfaces. He studied polarization, determined the lengths of light waves, and attributed to the ether the properties of a solid body, but he was somewhat frustrated by the phenomenon of diffraction of light, discovered like interference by the illustrious Italian physicist, Grimaldi of Bologna, who gave to the phenomenon the name by which it is still known.

This period was notable for a succession of discoveries as curious as they were unexpected. In 1808 the French physicist, Malus, professor at the École Polytechnique, discovered polarization by reflection when from his house he was examining with a prism of Iceland spar the image of the sun reflected from the glass windows of the Luxembourg in Paris; in 1811 Arago noted the beautiful colors of lamina of mica traversed by polarized light, as well as the rotation of the plane of polarization by crystals of quartz; in 1812 Biot brought to light new relationships between the reflection and the polarization of light by crystallized bodies; in 1813 Seebeck called attention to the polarization of light rays in passing through tourmaline, and Brewster to the colored bands about the axes of a double-axis crystal; and finally, in 1814, Wollaston showed the rings of Iceland spar.

Fresnel, in 1814, commenced the researches which led him from discovery to discovery with a speed unexampled in the history of science. His name is especially known to the public by his invention of the lighthouse lens, which bears his name and which replaced very advantageously the older reflectors. It not only augments the amount

of light but allows the economical construction of a lens of great size from glass segments of relatively small size in juxtaposition. The lamps constructed with Fresnel concentric wicks were twenty-five times more brilliant than those then in use. These inventions, however, were only incidents in his career.

He independently rediscovered the phenomenon of interference and at once tried to apply it to the explanation of phenomena of refraction in the wave theory. His success was complete; but learning that Young preceded him, Fresnel, a scientific hero, retracted any claim to the discovery.[3] Later he was to come in ahead of Young. Let us note here that there is no parallel to be drawn between the case of Young and Fresnel on the one hand, and that of Adams and Le Verrier on the other. For Young, self-taught, was a very great man, who had distinguished himself by the publication of original and splendid researches; whereas the remarkable mathematical discovery of Neptune was wholly due to the genius of Le Verrier, who shares the glory with no one.

Differently from Young, who considered luminous waves to be longitudinal like those of sound, Fresnel introduced for the first time the fundamental conception of transverse vibrations of the ether, that corner stone of the undulatory theory of light.

He proved that certain birefringent crystals did not follow the law of refraction of Snell and Descartes and formulated the true law. He showed the possibility of producing double refraction by pressure in glass prisms which ordinarily do not show it. The knowledge of that time was greatly extended and developed by his researches upon the phenomena of interference. With Arago, he brought to light the modification in interference in the case of two rays polarized in different azimuths. Then he found the law of the phenomenon shown by the colors of thin plates of doubly refracting crystals. The discovery of chromatic polarization by Arago was completed by Fresnel by that of circular polarization. Finally, his experiment with two mirrors giving interference fringes, alternately dark and bright, is classic.

Young, like Huyghens and Euler, could not reply to the crucial criticism of Newton regarding shadows. It needed Fresnel's genius. Through the latter's superior mathematical insight, it was shown that the inflection which Newton supposed should exist did occur behind opaque bodies, but that the divergent waves effaced each other, giving rise to shadows. His great generalization embraced in its first onslaught all the phenomena then known; further, the facts discovered by Malus, Arago, Biot, and others were not only thoroughly explained, but were shown to be a necessary consequence of

[3] In 1823 Young wrote that Fresnel had recognized "with the most scrupulous justice and most generous candor" the priority of his colleague upon this particular point.

the undulatory hypothesis. This generalization was truly impressive. Hamilton, of Dublin, taking up the theory later where Fresnel had left it, found from his calculations that at four points on the surface of the wave in a doubly refracting crystal the ray is not just doubly separated but rather broken into an infinite number of components. This was confirmed experimentally some time later by Lloyd.

As much an experimenter as a mathematician, Fresnel submitted the results of his calculations to the control of well-conceived and well-executed experiments. As he tried to visualize that which he suspected in the invisible theoretical domain, he often had recourse to imagination—that daring and wonderful faculty which, duly inspired and bridled, becomes the most powerful instrument of discovery.

The French Academy of Sciences opened its door to Fresnel in 1823. Filled with honors in France and elsewhere, he had the unhappiness of seeing his health, always delicate, weaken more and more. He died in his fortieth year at Ville d'Avray, July 14, 1827.

Fresnel was well judged by Tyndall, among others:

His brain was too vigorous for the body with which it was associated; that body prematurely became a ruin; and Fresnel left this world leaving behind him a name immortal in the annals of science.

There are things which are better than science itself. Character outweighs the intellect. It is particularly pleasant to those who love to think well of human nature to see united a great mind and an upright character. This union was found in this young Frenchman. In his ardent discussions of the undulatory theory he bore himself with integrity, claiming only his rights, and ready to accede their rights to others. He early recognized and praised the merits of Thomas Young. It was indeed Fresnel and his compatriot Arago who revealed to England the consciousness of the injustice done to Young by the Edinburgh Review.

I wish to read to you a short extract from a letter written in 1824 by Fresnel to Young, for it throws a pleasant light upon the character of Fresnel, the French philosopher:

"For a long time," writes Fresnel, "this sensitiveness, or this vanity, which we call the love of glory, has been much dulled in me; I work far less to gain public approbation than an approbation within myself which has always been the most pleasant recompense for my efforts. Without doubt I have often had need of the prick of vanity to arouse me to follow out my researches in moments of distaste or discouragement; but all the compliments which I have been enabled to receive from Messieurs Arago, de La Place, or Biot have never given me as much pleasure as the discovery of a theoretical truth and the confirmation of my calculations by experiment." [4]

Tyndall rightly saw in this letter an example to be followed. Science should be cultivated for itself, for the pure love of truth, and not for the applause or the material advantages which may accrue from it.

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[4] Six lectures on light, delivered in the United States of America in 1872 and 1873, fifth edition, p. 210, 211. This letter is dated Nov. 26, 1824.

SOARING FLIGHT [1]

By Wolfgang Klemperer

[With 11 plates]

I consider it a very great privilege to have been asked to speak to you within these venerable walls which have witnessed the infancy of many a discovery that later became a milestone of the progress of civilization. Flying is one of them. It was the dream of man for several thousand years. To this generation this dream came true by the most remarkable development of aviation, in which American genius played an important rôle. Man now can fly higher than the highest mountain, faster than the swiftest bird or cloud; the power of thousands of horses can be concentrated in an engine occupying but a few cubic feet capable of lifting many tons of freight into the air. On the other hand, we have also learned to soar in the air for hours without any motor at all.

Many people wonder how this is done, whereas the motor-driven airplane is quite familiar to them. Strange that it is not the other way around. For the great soarers among the birds—the albatross and seagull, the eagle, buzzard, hawk, and vulture—are masters of the art of flying without any expenditure of motive power. They display it before our very eyes, sailing without flapping their wings for hours at a time. Had their secrets been understood earlier, they could have taught man to fly long before any motor was invented.

In fact, the pioneers of aviation, such as Lilienthal and the Wright brothers, started on this track. It was by coasting down from hills in their early motorless gliders that they acquired the first real flying experience necessary to understand the basic mechanics of flight. Had not the automobile engine happened to be developed just at that time, the history of flying might have assumed an entirely different aspect. But thus, the rapid success of the motor-driven airplane seemed to render further gliding experiments unnecessary and it was not earnestly resumed until

[1] Lecture presented at a meeting of the Franklin Institute held February 10, 1927. Reprinted by permission from the Journal of the Franklin Institute, vol. 204, No. 3, September, 1927.

after the World War, which had brought a tremendous impulse to flying. This impulse had resulted in spectacular improvements of design and engineering, in a marvelous perfection of piloting and performance and, simultaneously, in giving scientists a chance and stimulation to advance theoretical and systematic empirical knowledge to a very satisfactory degree.

When gliding was resumed in Germany in 1920, it was done with the intention of applying this accumulated technical knowledge to the original problem of duplicating the soaring flight of birds. A meeting reunited those interested in the idea and organized the first experimental gliding contest. A camp was pitched near the top of Mount Wasserkuppe in the Rhön Mountain district. This mountain rises about 2,000 feet above the plain to its north, surrounded by smaller hills. Its slopes offer all topographical varieties from gentle grassy grades bare of trees to rugged gorges and fir-covered hollows. Initial success was modest, but we soon learned to make prolonged glides and we saw we were on a promising track. In the following year gliding developed into soaring. A series of duration flights increasing from 5 up to 20 minutes, some of them covering distances of a few miles and the first so-called cross-country flights without a motor, aroused nation-wide interest.

A society for the promotion of soaring flight was organized and now the Rhön Mountains have become a classic stadium of the air where annual meetings and contests are held. Glider schools and, recently, an elaborate permanent research institute were established there. Our primitive tents were gradually replaced by more permanent buildings; auto roads were built. No more the flyers themselves have to carry their own food and tools uphill in a two-hour hike from the nearest little town, sometimes getting lost in the heavy fogs or clouds which only too often justified the wet name of that mountain.

The year 1922 brought spectacular progress. It was due to favorable weather conditions during the three weeks of the meeting and to the lessons learned by designers and pilots in the preceding contests. The slopes of the Wasserkuppe, which formerly had not even been known to many, were crowded with thousands of spectators, who were thrilled watching the human birds for hours soaring above their heads, three and four at a time.

The absence of any motor and its noise, together with the slow speed of the glider flying against the wind, enables the pilot above and the crowd below to carry on oral conversation, and to furnish the flyer with meteorological information. Great emotion prevailed when the first one-hour mark was reached. The pilot, cruising at some distance from the peak, would every once in a while return to near the starting-point and the watching crowd and inquire about

how long he had been up in the air. When he had climbed too high for the voice to be intelligible, then scores of spectators would be grouped to form huge live numerals on the ground indicating the number of minutes flown.

Since then soaring has been taken up in various other countries as well, especially in England, in France (on the coast of the English Channel), in the Alps of Switzerland, Italy, and Austria, in the hills of northern Czechoslovakia, on the North African coast of the Mediterranean and in the Crimea range of southern Russia. In Germany, Rossitten, on the East Prussian coast of the Baltic Sea, became another center of soaring flight sport and research. Not to mention all the scattered hills where local glider clubs have taken up training for the bigger national annual events.

In spite of all this surprising development, soaring flight has not so far revolutionized the aspects of commercial or military aviation nor could anybody earnestly expect it to do that. The main reason is: Soaring depends primarily upon the wind exactly as a sailing vessel on the water does. Then many people will ask: What is it good for? This would be a question similar to: What is yachting good for in the age of ocean liners? There are three purposes for which soaring flight is pursued.

First of all, it is an unrivaled sport. I am unable to describe by words the sublime pleasure one experiences in gliding over hills and valleys, silently, like the eagle, cruising or hovering, rising or descending at will. The ample controllability makes you feel like them, master of the air. The constant alertness watching for favorable air currents and studying their relations to the varied scenery below provides thrill and challenge. A few weeks in a glider camp is outdoor life in the word's fullest meaning. Soaring flight requires also a certain amount of scientific training, engineering sense, and physical skill. Thus it most perfectly blends all the elements requisite for a recreational and educational sport such as the rising generation so appreciates.

Aside from this pedagogical value, the scientific research laboratories, both those governmental and those connected with the aeronautic industry, discovered a treasure in gliding. The most difficult problem in aeronautical science is the proper correlation between theory and research experiments on one side and the complex phenomena of practical flight on the other. The application and verification in practice of the results of theoretical investigations is often just as difficult as the laboratory investigation of some acute practical problem. The aerodynamical conditions in the wind-tunnel laboratory where models are tested in an artificial air stream are in many respects far from identical with those prevailing in actual flight. Gliding and soaring flight now offer supplementary experi-

mental means, as a full-size flying laboratory, for investigating problems in which the elimination of interference of a propeller slip stream with the lift of wings, stability, and control is essential.

A third field wherein the glider is useful is in the abundance of opportunity it affords for acquiring aerial experience which is of unlimited value in the training of future commercial and private flyers. Glider champions, as a rule, afterwards became superior airplane pilots, whereas the reverse did not hold so generally, although, of course, many of the new pioneers of soaring flight were much benefited by their previous extensive motor flying experience. No doubt, gliding constitutes an excellent means of initial aviatic training and has thereby already done much to make aviation popular and to promote air-mindedness.

In fact, any motor flight is terminated by gliding down to land. Of course, the idea of soaring flight is to glide not down but level or even to gain altitude. Now let us see how this is done without a motor.

Theoretically, we may distinguish between "static" soaring flight and "dynamic" soaring flight, although in practice they may overlap or blend.

The principle of static soaring is trivially simple. It consists in gliding down in a rising current of air. Provided the vertical velocity component of the air current exceeds the minimum rate of descent of the machine, any airplane can climb without a motor at a rate of ascent equal to that excess. A wind blowing over a vast plain, suddenly confronted with a large mountain range extending across its path, would, of course, be deflected upward. A wind blowing at, say, 32 feet per second up a slope 1:4 would furnish 8 feet per second lifting component. An airplane flying at 60 feet per second and having a gliding angle of 1:8, thus a natural rate of descent of 7½ feet per second, would still be carried up at ½ foot per second and yet proceed at 28 feet per second against the wind. However, this would soon carry it too far upwind, out of the zone of vertical deflection. This is why the soaring birds and experienced glider pilots cruise weaving to and fro along the mountain ridges, always trying to keep within the zone of strongest lift.

Of course, the wind does not exactly follow the contour of the hillside in equidistant flow lines. As far as the windward side of the wind obstruction is concerned, model experiments in wind tunnels have given interesting results and perspicuous flow pictures can be derived by calculation, using the method of sources and sinks. A combination of sources and sinks is so chosen that the fictitious fluid produced by these sources and washed leewards by the flow representing the wind is completely housed within a shape that coincides with

the contour of the mountain. Then the direction and magnitude of the local velocity anywhere in the field can be calculated by simple geometrical addition of the horizontal wind to the resultant influence of all sources and sinks upon that point.

Since the equations of the stream lines happen to be identical with the equations of the equipotential lines in an electric field, several investigators have made experimental use of this remarkable analogy and derived flow structures by electrically sounding in a tank filled with an electrolyte between electrodes shaped according to the boundary lines of the flow problem.

Actual full-size measurements of the wind texture on the windward side of the coast at the Rossitten soaring flight site were accomplished last summer by taking motion pictures of the clouds left by smoke rockets fired up to various heights. The results of these experiments and others made with ammonia clouds revealed that the acceleration of the wind right above the crest and the upward deflection at the bottom of the slope are somewhat smaller than would be expected from the analogous potential flow. Explanation is anticipated to be found in friction and the thermic gradient.

The best locations for static soaring are usually to be found at some distance windward off the crest. The useful zone may extend to considerable altitude, at times twice as much as the height of the mountain above its base. Obviously, the vertical deflection component decreases with higher altitude. Thus a glider which has a well-defined minimum rate of descent will find a definite "ceiling" above the crest, beyond which it can not climb in static soaring. Very favorable conditions occur above horseshoe-like formations of gorges. The leeward side of the mountain is feared for its treacherous descending currents, weird whirls, and dead zones.

It is easy to see that there is no fundamental difficulty in remaining aloft for an unlimited duration as soon as the pilot has found a sufficiently wide area of sufficiently strong rising wind currents, as long as he sticks to it and the wind endures. In fact, some of the duration record flights were made by patiently cruising in figure eights above the same place and extended far into night-time, when landings had to be made in the light of automobile headlights and flares. The longest duration ever flown by a glider was 12 hours and a few minutes, attained by Herr F. Schulz in 1924 on the Rossitten coast.[2] The same pilot has later flown nine hours with a passenger.

It is considerably more difficult to cover large distances, however. The first distance flights were made by climbing to the

[2] On May 5, 1927, he beat his own record, staying aloft 14 hours 7 minutes.

"ceiling" and then taking a flat glide across or more or less with the wind. Later we learned to pick up altitude under way. At Rossitten, Herr A. Martens managed to sail all along the chain of coast dunes for some 15 miles and back to his base. The plucky Darmstadt college glider team finally perfected the art of sailing from mountain chain to mountain chain across valleys and plains. A wonderful feat was the winning of the Milseburg prize by Herr Nehring, their youngest member. The task was to start from Mount Wasserkuppe, to fly to the Milseburg, an ancient rock castle some 7 miles distant, to circle it and to return to the starting point, without a motor, of course. After climbing some 500 feet above the crest in a moderate wind blowing about across the direction of his goal, he crossed the valleys and intermediate hills and arrived near the castle in good fashion. Due to other hills surrounding the Milseburg and impairing aerial conditions there, he lost a good deal of height. Thus it looked as though he would never be able to complete the return trip. However, by making clever detours to the windward slopes of various other hills, he managed to gather enough lift again to negotiate the worst gaps and valleys and finally alighted only 400 feet from his starting point. This flight strikingly demonstrated what tremendous possibilities long-distance soaring in hilly country presents.

Vertical currents are not entirely confined to mountainous regions. Every cumulus cloud is the top of one. The variations of solar radiation and of the thermal capacity of different varieties of soil cause the atmosphere to heat very irregularly. Above some localities hot air rises, above others cold air descends. In tropical regions such thermical drafts attain formidable velocities. In Guinea, Central Africa, the French scientist P. Idrac has measured vertical velocities ranging from 2 to 5 feet per second. By means of kites, he lifted wind-speed meters up into the strata where vultures were soaring at the time.

Airmen do not like to fly in clouds. However, they are visible indicators of the rise of saturated air. To glide not only from mountain to mountain, but also from cloud to cloud, was the ambitious goal the soaring flight pioneers had set out to attain.

During last year's Rhön meeting, the German pilot Herr M. Kegel was caught by a thunderstorm. Threatening clouds came rapidly rolling up toward the Wasserkuppe. Two other pilots who also were in the air decided to land. Kegel, however, drove right up to the front of the monstrous roller and clung to it. Soon he was out of sight of the amazed spectators. He let himself be carried by the clouds' upwash as high as about 4,000 feet, and thus actually traveled a distance of 40 miles. Eventually, he headed leeward out of the region of the disturbance and beat

the storm for a safe landing. The whole flight had lasted three-quarters of an hour. According to his own account, he must have had a thrilling time when he was bounced about by the violent cross currents in that aerial whirlpool, visibility at times completely extinguished in the dense mass of turbulent foam. There is no doubt about Herr Kegel's ability as a pilot, but it may be mentioned that he had also built his machine himself in his spare time and it was one of outstanding efficiency and workmanship, too.

There is some advantage in flying in adverse weather. Quite a number of spectacular soaring flight events were indeed distinguished by rather unsettled weather conditions. The stormier, the greater the chances for reaching high altitudes. Gliders have often climbed 1,000 feet above the crest of the mountain. Since 1921 the gliders were out in any weather up to gales of 45 miles per hour. Only a dead calm would confine them to idle waiting. What a difference from the state of affairs during the early days of motor-driven aircraft. No airman will deny that learning how to buck gales immediately close to mountain ridges constitutes a very valuable training for meeting unexpected aerial situations.

In a flat country, even in the absence of meteorological disturbances, vertical currents may be induced, for instance, at the border line of a smooth and a rough surface. Imagine the wind blowing over a great grassy plain or a great body of shallow water, then striking an adjacent forest, the trees of which obviously absorb more energy per unit of area. The friction layer in which braking impulse is transmitted will here extend higher than above the smooth plain. The retarded air has no other escape but upward deflection. Ravens and buzzards can sometimes be seen soaring a short distance leeward of such border lines of surface roughness.

When one only temporarily happens to find profitable upward currents, it is obviously best to concentrate production of lift during these favorable periods, by rising or by storing kinetic energy in order to gain some reserve to draw upon while negotiating the lull. In fact, the wind is almost never like a viscous stream. It contains turbulence and there is something like one-third of the chances for the occurrence of vertical turbulence components. Fortunately, the mere inertia causes any airplane to gain from such vertical pulsations a slight increase in lift or a slight reduction of drag. Katzmayer, in Vienna, proved this by model experiments in the wind tunnel, introducing artificial cross-wind pulsations. The theoretical explanation of the phenomenon is this: Any upward fluctuation causes the relative air stream to strike the wings at some inclination upward, thereby inclining the resultant air force forward. In the descending phase of the fluctuation the reverse holds, thus in-

clining it backward. The pull of the first case and the additional drag in the second would eventually cancel out, if they were of equal magnitude. However, in the rising phase the angle of attack and, consequently, the lift are increased, in the descending phase they are decreased. Therefore the forward component wins. Lift is automatically concentrated during the period when power is transmitted from the air to the machine. The airplane combs the fluctuation. We often call this phenomenon the "Knoller-Betz" effect, after the names of two scientists who independently published the first explanations in 1912 and 1913. It may be that this is the same phenomenon which causes discrepancies between the results of wing-model tests conducted at various laboratories or under different conditions of turbulence.

Flying through vertically pulsating air, the operation of the elevator in a certain rhythm, would yield an optimum power gain a little in excess of that natural gain which would be derived from inertia alone. However, there is no conspicuous periodicity in the vertical wind fluctuations and it would be extremely difficult for the pilot to estimate their harmonic constituents and, above all, to discriminate in time between vertical and frontal gusts.

The utilization of the latter is a different proposition and leads us to dynamical soaring proper. It is obvious and well known that the horizontal mean velocity component of the wind can not be captured from any free-flying vehicle. It can be by a kite which is connected to the solid ground by a cord.

Soaring flight is in some languages called "sailing flight." The comparison with sailing does not lack some justification. The sailing vessel depends upon its simultaneous contact with two mediums, the sail with the air, and the keel with the water. Without the keel part it would be helpless. A round nutshell without a keel would drift uncontrollably with the wind. So would a sailed ice sled put on balls. Furthermore it is only the relative motion between these two mediums that can be utilized. When the wind blows with the same velocity and direction as the river flows, sails are dead and worthless to the river craft.

Now, where is the other medium to lean against from an aircraft totally surrounded by nothing but the wind? It can only be portions of the wind which move at velocities different from the average. The wind is almost never uniform. In one place and at one instant it moves faster than at another. It is these irregularities from which, in dynamic soaring, energy is drawn. Conventional types of aircraft, contrary to naval craft, lacking the advantages of maneuvering at the contact surface of two media, can not get hold of them simultaneously. Thus we have to merge into each of them alternately, relying on inertia as a substitute for the mast and rigging.

On a sailing boat, the angle of attack of the sail by the wind and that of the keel by the water lie toward opposite sides. The equivalent condition has to be brought about in dynamic soaring by facing the two portions of the wind in opposite directions. This involves certain maneuvers which deserve some particular investigation.

Let us consider an idealized form of gustiness. Imagine the wind to fluctuate between the extremes of 20 and 60 miles per hour. Let the acceleration during the freshening period be constant, say 4 feet per second^2, or one-eighth of that of a dropped body. It would take 10 seconds between two extremes. Suppose we had been flying facing the slow 20 miles per hour wind. Now the wind freshens up. If we should not react, we would gain excess speed against the air due to our own inertia. However, we do not want more speed, since our lift just balances our weight. Thus we decide to throttle down our motor, and assuming the drag of our machine to be one-eighth of its weight, we could just shut off that engine completely. Our drag would just retard us so much that our speed against the swelling gust will be constant, and we continue our level flight, without any propulsive power other than the reaction of inertia. However, this condition will last only 10 seconds. Upon reaching the climax of the gust, the negative acceleration of the calming-down period would have a retarding effect on us and we would need twice our normal engine horsepower in order to catch up with it. After completing the cycle we would have gained nothing at all. However, the idea of this sort of dynamic soaring is not to wait until the lull spoils the temporary gain, but to turn away in the meantime. Then when the calming-down stroke arrives, one is headed already the other way and gets another free lift equal to the preceding one, since now we transport the impulse from the fast wind portion into the slow one.

This manipulation is by no means a mysterious case of perpetual motion. In fact, the airplane or bird so circling picks energy from that stored in those meteorological irregularities. Its action somewhat resembles that of a traffic cop on the road, slowing down fast elements of (wind) traffic and speeding up slow ones, with the result of smoothing the entire motion. If he does a good job there is nothing left for his fellow farther downstream to do.

It is interesting that not the actual accelerative structure of a gust is what counts, but the average acceleration only, between the times of change of course of the craft. If this is the same or more in proportion to gravity than the ratio of drag to lift of the airplane or bird, the soaring effect is 100 per cent. The conditions assumed in our numerical example happen frequently in the atmosphere, and, since we can refine glider design so as to reduce drag to one-twentieth of lift, chances of riding the gusts would not look sad at all. How-

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ever, it is very difficult for the pilot to foresee what is going to become the peak of a gust.

Besides, it is impossible to make an infinitely sudden turn. Thus one has to turn away from the gust quite a little before he gets his full share of the beneficial acceleration nor will he have reached quite the opposite flight direction on time to get all of the reverse. In addition to this, even a quite moderately banked turn consumes an additional tribute of power in the form of the increased drag induced by the increased wing lift necessary to overcome the centrifugal force of the turn. Thus, after all bills are paid the profit is materially cut down. For instance, if one simply circled "synchronically" in a slow but powerful gust of harmonical rhythm, he may practically gain about one-third of the energy theoretically available.

On the other hand, if satisfied with only a fair fraction of the entire possible gain, you may fly across the wind and merely sway from your course somewhat in serpent fashion, corresponding to the lateral accelerations, always with a trend of keeping weatherly. In fact, this is a very reasonable method to be resorted to when flying along a mountain ridge, and in some instances I am quite sure I picked some valuable gain from such lateral gusts this way. A Frenchman, Mr. A. Sée, demonstrated how energy can be gained from lateral gusts by merely rolling the machine while yielding to the yaw, so as to present the raised wing always to the luff side. However, every pilot knows this to be a somewhat delicate maneuver and trying it I once almost heeled over in the face of a rugged peak, having underestimated the force of a blow which apparently shot from an adjacent gorge. The excessive banking and subsequent recovery by a dive spoiled more altitude than had been gained.

If the gust is also accompanied by a variation in wind direction, this can be quite useful to a glider endeavoring to take those unavoidable turns always in the sense of the turning of the acceleration vector. Indeed, an optimum condition would be what may be termed a circularly polarized gust. An airplane properly curving would be centrifuged like a heavier particle in a rotary separator. Trying to head toward the pole of the whirl, the ship would be dynamically impelled. Whether similar conditions actually occur in the atmosphere outside of tornadoes, I do not know.

We have seen the necessity of performing some sort of a change of flight direction during the climax of a gust. But there is no reason why it is confined to the horizontal plane. Someone may prefer to do it vertically. However, by mere analogy it can be seen that it would take continuous looping the loop, synchronous with the oscillations of the gusts in order to get anything like a fair portion of the entire available energy. This is impossible. Again, a fraction of it is obtainable by performing certain vertical rocking movements.

They are characterized by alternating pulling up and diving down synchronously with the acceleration phases of the gusts. The important thing about them is that they must consist of at least one primary oscillation and its first harmonic. Thus in a harmonic gust the two branches of the path will look unsymmetrical, the diving part being done somewhat steeper than the climbing. The mechanism of this performance has been compared to making a car travel uphill on a scenic railway structure by oscillating the whole structure horizontally, in the plane of travel. It is quite possible to derive some profit from occasional strong gusts by this rocking method, but it would be in vain to hope to rely on this alone for support.

Horizontal and vertical gustiness of the wind may occur combined. When they happen to be synchronous, their relative phases are of importance. Professor v. Kármán has shown that, in proximity to the ground, the surface friction causes the combination of freshening and descending or of fading and ascending to occur more frequently than the reverse. For any particle coming down from above, where velocity is greater, brings forward impulse with it; whereas any particle that happens to rise from the retarded layer below carries braking impulse with it. This reasoning would lead us to believe that an airplane flying low over the ground would gain less when headed against the wind, but more when fleeing before the wind, as compared with what it would gain from vertical oscillations without a horizontal component.

The same principle can be applied to explain a long-known phenomenon which has puzzled early experimenters. A light wind vane balanced and mounted on a horizontal axis, intended to show the vertical inclination of the wind, seems to indicate an upward trend of the average of the irregular fluctuations amounting to some 2 to 4 degrees on a level plain. Of course, the wind can not spring from the ground. The explanation is that the rising elements are slower, the sinking elements are faster. Thus although no more air rises than falls, on the average, the apparent angle of the resultant motion is greater for the slower, and smaller for the faster particles. The mere time average of the direction of an irregularly fluctuating vector has no physical significance.

Really measuring the vectorial fluctuations in the atmosphere is a very interesting but delicate technique. The introduction of the electrical hot-wire anemometer and directional anemometers into micro-meteorology promises many scientific possibilities. Electrical anemometry is based on the principle of exposing a fine platinum wire electrically heated to the air current to be explored. The temperature the wire assumes under the cooling influence of

the air flow is electrically measured or controlled and with reference to the power input gives a clue to the local velocity.

The regions of different wind-speed travel in the turbulent atmosphere and the great difficulty is to anticipate when they will strike you. However, there are also places where they can be found quite stationary. On the leeward side of a blunt wind obstruction there is a dead zone, a wake, so to speak, a short distance adjacent to which the wind may blow at full force. Seagulls, swallows, and swifts are masters of the art of soaring back and forth between such layers. The mechanism of the capture of kinetic energy is very similar to that of circling in gusts. The bird glides in the dead zone toward the tower, wall, bosket, or whatever forms the obstruction to the wind. Suddenly the bird weaves across the contour line of the dead zone into the open wind where, due to its inertia, it receives a powerful lift. After having made enough headway against the wind, it circles and coming down-wind shoots back into the dead zone, where the tremendous velocity it has acquired is a big store of kinetic energy which is gradually used up in patrolling for food until it becomes necessary to resume the cycle again.

Nobody would suggest trying to duplicate such stunts with gliders, because the combination of the human brain—hands—steering mechanism—moment of inertia of the wide-spanning machine is very much slower than the corresponding chain of reaction within these birds, and chances would merely be of crashing into some rock. However, layers of different wind velocities may often be found one above the other. As a rule the wind higher up is faster than down below. The energy stored therein can be caught by alternately gliding downwind in the upper layer, descending into the lower one where the relative surplus velocity is kept in reserve, then turning around and pulling up into the upper layer again. Here a powerful inertial lift is the reward of the whole maneuver. Vultures have been seen circling this way in India, descending and ascending rhythmically in inclined orbits.

In places where the discontinuity zone separating the two layers is sharp, this phenomenon is even noticeable on regular motor airplanes. In the Karst Mountain range behind the east coast of the Adriatic Sea sometimes a peculiar meteorological condition occurs. A strong uniform westerly warm wind, called sirocco, sweeps in from the sea at the higher altitude. Cold air, called bora, rushes down the slopes of the bare mountains, mainly from an easterly or northeasterly quadrant. Wind-speed drops as sudden as 60 feet per second west against 15 feet per second northeast can be encountered in passing down from the 2,800-foot level to about 2,000 feet. Flying there,

we experienced the sensation that in trying to spiral down one way we were unable to bring the machine down to land on the flying field in the hollow, the motor throttled way down, whereas circling the other way around between the mountains, we would be knocked down so vehemently one had to open full throttle again to prevent crashing into the rocks that lined the field. It may be superfluous to mention that the inversion zone was rather rough riding and bumpy, too. Sometimes the altitude of the zone of wind inversion was indicated by peculiar formations of many small clouds rapidly forming and disappearing. I should not wonder if similar conditions may be encountered in parts of the Rocky Mountains, also.

Even without a pronounced border surface between two distinct wind layers, there can be energy stored in accessible form where the wind is gradually increasing with altitude. This sort of power gain is most suitable for a machine capable of a high rate of climb. The gain in terms of the original rate of climb is approximately equal to the proportion of gravity to which the product of the vertical gradient of the wind velocity and the forward speed of the airplane amounts. This is the reason why, even above a level plain, airplanes generally climb better against the wind than before the wind, which, after the very take-off, would make no difference if the wind did not increase with height. A racer would experience a difference of about 20 per cent in the rate of climb between the two directions of flight in an atmosphere where the wind speed would increase by 10 feet per second per 1,000 feet altitude, which is not exceptional.

An interesting suggestion has been made by a Bavarian inventor, Herr Wolfmüller. His device is the true aerial counterpart to the sailing boat, and really deserves the name of sailing flight.

His argument is this: The sailboat uses a high mast to make the sails reach way up into the strong wind. Why not build the airplane so big that its upper and lower extremities extend into different layers of wind, the upper wings to act as sails, the lower ones as a keel? The idea sounds fantastic. But what he actually did is to fly two kites, one raised way up high, the other one kept low. The two strings were tied together and let go. On evenings when the wind was known to blow from the opposite direction at the higher level than down close to the ground, these kite teams would travel many miles, and he did not always recover them. Being of rather elaborate design, they even could be stabilized at certain relative angles and made to travel across the wind at considerable speed, just as a sailboat cruises. Interesting though the principle may be, it is not very likely to be put to practical use.

The principles underlying the various methods of dynamic soaring flight may seem to many rather remote ideas. Yet dynamical prob-

lems are not at all strange to everyday life. There is a rather peculiar financial analogy to soaring flight, viz, making money from dynamical sources. Soaring in gusts is ruled by much the same conditions as buying and selling stock, always making a change of policy coinciding as best possible with every climax. Soaring between stationary wind layers is equivalent to trading across international boundaries, buying merchandise where there is abundance of it and importing it to where it is lacking. The loss due to centrifugal force represents the freight and import duty. Dynamic climbing in a vertical wind gradient is very strikingly paralleled by the business condition in a country where currency is being inflated, the inertia of the money devaluating during circulation being essential for the profit of those who issue it and the loss of those who furnish the values. Even the deeper cause for the maintenance of such an unstable situation, being some greater disturbance of much bigger volume than the individual's concern, finds its perfect parallelism in soaring flight.

Practical soaring flight depends not only on the wind structure and the pilot's skill, but also to a large extent on the design of the glider. Theoretically, of course, any airplane can be flown as a glider provided plenty of power is presented in the aerological situation to meet the modest aerodynamic efficiency of the machine. Extended soaring flights have indeed been made with regular airplanes, the motor just shut off, for instance, by the French lieutenant Thoret on a horseshoelike bay on the North African coast.

The most interesting development, however, was that of the modern gliders, machines specially designed for use without a motor. In their design lightness in spite of strength and aerodynamic refinement were carried to unusual extremes, which later did not fail to have some marked influence upon modern design of motor-driven aircraft, too.

The structures of most gliders are made of wood. Very thin plywood varying in gauge from three thirty-seconds down to one thirty-second of an inch for the total of the three plies, is the preferred material. Wooden beams and trusses joined by plywood gusset plates are assembled to the most intricate and elaborate internally trussed bridge works. Cantilever wings weighing less than 5 ounces per square foot are built with ample strength. Waterproof casein glue is used exclusively and nails are religiously avoided by many designers, since with a well-glued joint they contribute nothing to strength but considerably to weight and deterioration. The weight of successful gliders varies from about 250 pounds down to as little as 90 pounds. Two people can handle them on the ground.

Much ingenuity has been displayed in facilitating disassembling and road transport. This feature was a great asset for the contestants after long-distance glides in the hilly country.

In the glider field the question of monoplane or biplanes has been rather decidedly settled in favor of the monoplane. Extremely large aspect ratio (=span: wing chord) became some sort of a dogma. The production of lift by wings is inseparable from evoking induced drag, proportional to the square of the load per wing span. In the glider, all protruding structures being carefully avoided to a much greater extent than is possible on a motor airplane, the more the ideal of the nothing-but-wing machine is approached, the more the induced drag becomes decisive for efficiency. Theoretically this was quite well understood. It was the merit of the gliders to have practically proved the correctness of the theory of aspect ratio and induced drag in full size. Wing spans consequently grew wider and wider and wings spanning twelve times their chord became quite common. A gliding angle of 1:20 was reached with them. Of course, in order to accomplish this it is essential also to avoid struts and external bracing, with their parasite resistance. Structurally, it is quite a task to build a light wing spanning 30 feet from root to tip on the cantilever principle, having only 5–foot base depth or less, at the root. Responsible designers of the old school were quite hesitating to risk something like that, so it took the boldness of college students to demonstrate that it can be done. The idea of the large wing span was in the course of events perhaps exaggerated and overemphasized by amateurs. A few accidents due to wings failing by torsion or vibration happened, although none of serious consequences to the pilots. They had the welcome effect of stimulating research on wing flutter, which since then has greatly increased knowledge for its prediction and avoidance.

The tapering of wings toward the tips has been demonstrated to contribute enough to structural and aerodynamic efficiency to justify the manufacturing complication. The gliders have done much to demonstrate the merits of the thick and semithick wing sections, and the advantages of well-rounded leading edges for a wide useful range of angles of attack, whereas the particular merits of one or another special wing section are often overemphasized.

Nowhere can thé suppression of parasite resistance be carried to such a perfection as in the modern glider. Some of them resemble a bird in a striking manner. There is nothing but a wing, a tail, and a stream-lined body, just large enough to tightly house the pilot. Every aviator will agree that the field of vision from a glider's cockpit is perfect, incomparably better than from that of any regular

tractor airplane. One can see to the last second the very spot where he is going to land. In fact, there was hardly anything as thrilling as the various spot-landing contests which have been a regular feature in glider meetings since 1922. A plot is marked, a few square feet on a lawn on a plateau a couple of miles distant from the hill where the gliders take off, and only about 100 feet lower in level; a place which could never be reached by mere gliding without soaring. At the 1923 Rhön contest the prospective victor having alighted only 50 feet from the goal, was quite surprised to be beaten in the last hour by some one who made 35 feet. This was considered pretty good among aces. It was only the average in last year's contests when the records followed in rapid succession: 210, 131, 105, 65, 62, 48, 32, 28, 20, 19, 18, 15, 11, 8, and 6 feet. There would be no sense in trying to beat such performances. But this reflects very strikingly the wonderful training the glider pilots acquire, too.

Glider training is lots of fun. On account of the slow velocity against the wind, and of the absence of any combustible fuel, the danger and hazards are remote. A smart high-school boy of 16 once learned gliding in his own homemade machine by being towed like a kite and his instructor running alongside and shouting up to him what to do with the controls. A preferred method of training is now to first give the student some rides in a two-seater glider with dual control, before he is turned loose to solo on a very sturdy and foolproof training glider. Then he is put on a more sensitive type for advanced training until he may try to compete in the contests on the highly refined champion machines.

A very striking development of glider design is the single-track landing gear. Wheels have been abandoned not only for their resistance in the air but also on account of difficulties in coming to a stop when landing on an incline. Most gliders are equipped with skis as originally used by the Wrights. Some sort of springs are preferably inserted between skis and body. It was found quite feasible to land on one single central ski, in spite of the largest wing span. The pilot can manage lateral stability with the flaps until the machine comes to a standstill. Then it may tilt over so one wing tip may rest on the ground. A glider can safely be landed in places that would scare any motor airplane pilot to death, in underbrushes, in hollows, on steep inclines, or jumping over boskets and fences. After having stalled in the air, flying speed may be recovered after a drop of something like 25 feet.

Quite a number of rather unorthodox designs have been built and flown as gliders with interesting success. Among them are tandem wings, tailless planes, with pronouncedly swept-back wings, slotted wings, machines having the control planes in front of the main wings,

and others incorporating flapping wings. An interesting experience was gained with an extremely light tail-first machine. It became longitudinally unstable when starting, due to the vertical gradient of the wind close to the ground, it is believed.

The normal gliders are equipped with elevator, rudder, and ailerons, and are controlled very much like "real" airplanes. Control surfaces are often comparably large, but the length of the tail is short in comparison with the wing span. Many efforts have been made with a view to eliminating the vertical rudder. The birds have evidently quite good control without it. However, all attempts at copying the ideal warping and folding mechanism of the birds' wings or at replacing it by some other device have not so far produced anything decidedly superior to a rudder. Various kinds of wind brakes mounted on the wing tips, which on a glider have such a long leverage, have been tried with partial success. Flexible camber wings and tiltable wings have been flown quite successfully, although the advantages claimed do not seem to be exactly in proportion to the complication. Some device with which to control the gliding angle independently of the angle of attack and speed does have some definite usefulness, however.

Some inventors believe certain special wing and steering mechanisms to be capable of performing dynamical soaring flight automatically. Such devices, it seems, are not very likely to meet with success. There is a fundamental difficulty involved, closely connected with the problem of distinction between vertical currents and horizontal gusts and with the correct utilizing maneuver depending on more than what can be mechanically and aerodynamically grasped from aboard. In practice, the interpretation of the sensation of equilibrium depends to a large extent on the visual observation of what happens. One can fly with his eyes closed for a while, but not a bit in dynamical soaring. Neither can a bird in pitch-dark night. Most of those inventions are the involuntary result of a confusion of the problems of dynamical soaring and that of stabilization in straight flight. The two problems are by no means identical. In fact, the stabilizer is intended to make the machine let the gust pass as unnoticed as possible. In dynamical soaring, on the contrary, the gust must be responded to by a vigorous motion in order to wrest energy from it. However, there is a deeper meaning to this confusion: The knowledge of the direction of gravity is a fundamental condition for any creation of a lift with which to oppose that gravity. On the solid ground or even on a big and sluggish air liner in calm air there is no difficulty to that, and we are so familiar with it that we are thoroughly accustomed to consider the direction of gravity as an established reference basis. Yet, on a glider performing dynamical

soaring flight it becomes quite an indefinite fiction bare of sensible qualities. The reason for it is that all dynamical maneuvers involve actions of inertia, and it is just the task of the dynamically soaring machine to steer in such a way that the inertia forces do not on an average cancel out, with respect to axes inherent to the craft. Thus, dynamical soaring is the true materialization of Einstein's famous fictitious box within which all mechanical means completely fail to distinguish any essential difference between inertia and gravity. Once the two are entangled they can not be separated by instruments.

In order to describe fully the status of motion of a body freely moving in space, we have to state six elements, the three components of velocity and the three components of rotation in space. All mechanical instruments based on the principles of masses, springs, liquids, pendula, and gyroscopes combined and carried on board the aircraft are subject to the combined influence of both gravity and inertia, too. So, in order to determine the vector of gravity we have to subtract from the resultant the vector of inertia. We can measure by six aerodynamical instruments such as anemometers and wind vanes the six equivalent data about the relative motion of the ship in the surrounding air. This suffices, evidently, in calm air.

However, as soon as I suspect, or know, that the atmosphere is involved in an irregularly accelerated motion with reference to the earth, I am at a complete loss to determine the amount of the influence of this fact by means of any instruments of mechanical or aerodynamical kind carried aboard. The unknown data must be supplied by having recourse to other physical fields. In practice, I mentioned, it is the field of vision. To do that automatically by means of instruments is at present pretty well beyond available instrumental facilities. Theoretically, instruments utilizing such extraneous fields as the magnetic field, the dielectric field or the air-density gradient may be given consideration, but whether sufficient accuracy and quick response will ever be attained is hard to fancy. Besides, weight, bulk, and complication are big handicaps for the use of automatic apparatus and even instruments in general.

Just the same it is of great scientific interest to investigate with whatever instruments are feasible, into the details and intricacies of soaring flight. Recording altimeters, air-speed meters, and so-called accelerometers, which, however, are really not indicating acceleration proper, but a component of the resultant air force, have been of great assistance to both pilots and students. You can, while flying, by watching these instruments simultaneously with the horizon and the other physical sensations, interpret much better whether you are gaining or losing energy, in every phase of the gust. Angle of attack and yaw meters, however primitive they may be, are also a valuable asset. A wealth of information has been accumulated

lately since elaborate surveying stations were installed on the Wasserkuppe and Rossitten gliding centers. A number of continuous surveys of outstanding flights were recorded stereographically and evaluated afterwards, reconstructing the complete path of the glider in space. This work was originally started by taking synchronous readings from a theodolite and a range finder, but later on these instruments were replaced by pairs of kinema-theodolites disposed at the ends of bases, about one-eighth of a mile long. Several pictures were thus ground per second, insuring a very dense record.

Not only true soaring flights were thus surveyed, also special straight glides were taken occasionally on particularly calm mornings. They served to get the aerodynamic characteristics of the machines themselves, independent of any soaring action.

The application of gliding to scientific research is at present somewhat limited by the method used to get the glider started. It requires the windward slope from a mountain crest, whence it is catapulted into the wind by means of a rubber cord pulled by a crew of from four to eight people. In hilly country this method works exceedingly well; but one had often wondered how much more gliding would be popularized if some method of take-off could be devised to depend less on topology.

I once tried to attach the glider on a captive balloon of the Swiss air service, and to take off from there. The glider was suspended some 100 feet below the basket, slightly aft of its own center of gravity, to keep its nose down. Unfortunately, this entire system being a gigantic double pendulum, immediately started to perform lateral oscillations. The balloon would yaw and travel to one side, the plane would prefer the opposite side. The motion was not fast but amplitudes were increasing. I was unable to check the oscillations by use of my controls. Since the machine would also always bank toward the wrong side I was forced to cut loose only to be thrown into a spin to recover from which the altitude was insufficient.

There remains [3] the possibility of fitting the glider with a small auxiliary engine, just as they do on sailing yachts. Thus the glider may take off in the plains and fly under its own power to any place, where, upon meeting soaring flight conditions, the engine is throttled down or shut off and the real sport begins. The auxiliary engine would also help out a glider that happens to drift away from lifting currents or runs into a dead calm. As a matter of fact, a modern

[3] Quite recently Herren Espenlaub, Raab, and Katzenstein made successful experiments by having a glider attached to and towed by a motor-powered airplane. Having been so dragged to considerable altitude, they cut loose and glided back to their base. They also towed a glider from one town to another via air.

glider requires no more than about 1½ horsepower net for sustentation. All kinds of motorcycle engines have already been tried, varying from the smallest 2-horsepower variety of light European bicycle motors up to the size of four-cylinder racing motorcycle engines. Remarkable flights were made with such machines, taking off on as little as 7 horsepower as well as soaring with the motors shut down. Clever devices were designed for starting the engines up again while in flight. However, it soon became evident that available motorcycle engines were not thoroughly reliable and suitable under the conditions of flight. The British motor industry was the first to visualize the necessity of developing from the motorcycle engine a special light aircraft motor. Horizontal twins, two-cylinder V-types, four-cylinder block and three and five cylinder radial motors now cover the range of 25 to about 60 horsepower, which is usually referred to as the light airplane class. All of them are air-cooled.

Startling flights were made with astonishingly low-powered machines, which demonstrated that the real light airplane, as developed from the super-efficient glider, is by no means a fine weather craft but can be put to very severe service and yet retain a great deal of the poetry and sport romance of the true glider. It was with a tiny 25-horsepower, two-cylinder motor in his neat little monoplane that Botsch two years ago flew more than 300 miles from the Rhine to Berlin in 3½ hours. A Messerschmitt two-seater cantilever monoplane of 40-foot span, powered by a similar engine, crossed the Alps at 13,000 feet from Bavaria into Italy under the most adverse weather conditions. Mileages as good as 60 miles per gallon are not uncommon with the light planes. The most striking feat was Botsch's victory in a competition two years ago, for a flight circling Mount Zugspitze of the Alps, 10,000 feet, starting from and returning to Munich. He won first prize with a small 14-horsepower light plane against competition of all classes, among which were motors as strong as 200 horsepower, since the prize was to be awarded for the least consumption of fuel. He used only something like 2 gallons, doing everything else by deliberate soaring flight, skillfully utilizing the various currents in the mountainous country.

Unfortunately, among the motors at present available, there seems to be none that meets all of the ideal requirements at once, such as a really low weight per horsepower, fair number of cylinders insuring perfect balance on a light mounting, irreproachable reliability under flight conditions, little wind resistance, and last but not least a popular selling price. As soon as this goal is reached there will be comparatively little difficulty in building a reliable and fairly foolproof light airplane of high efficiency, and capable of soaring flight,

accommodating two people, slow and safe to land, of amazing fuel economy and negligible maintenance cost, the wings to fold back for housing in any garage. There is little doubt that this generation will live to see and use it and flying will become as popular as motoring. Only then, the interesting possibilities of soaring flight will be realized and the results of past research applied. Pure soaring will not fail to retain a favored rank among outdoor sports.

In Europe, gliding has contributed very much to the popularization of flying by bringing the younger generation into active contact with it. It is organized and stimulated by various disinterested private societies for the promotion of aviation. It is not, in general, a quick return business proposition. But I hope to have shown that it combines sport with education, art, and scientific research, a combination rare in this materialistic age and not unworthy of encouragement from those who consider it a sacred privilege to contribute toward the development of new art and science.

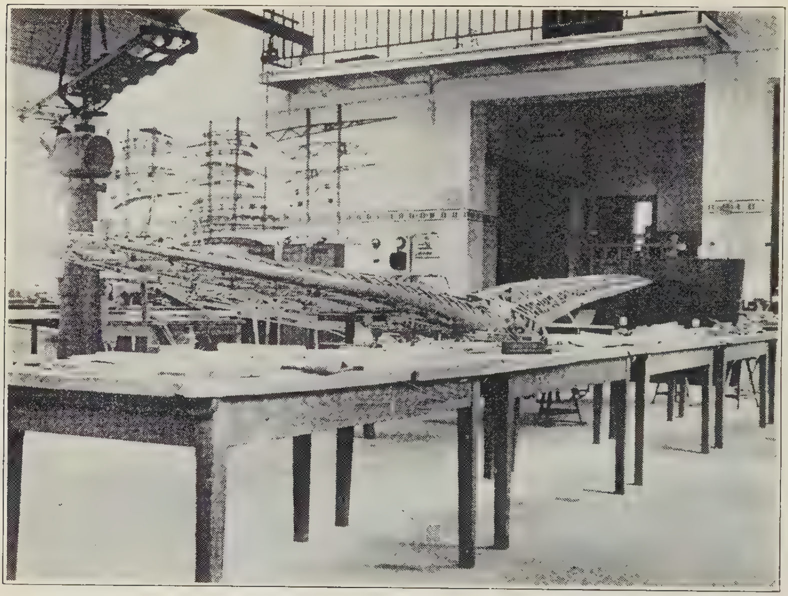
ABOVE THE RHÖN COUNTRY

1.—WAITING FOR WIND

2.—A TAKE-OFF. NOTICE THE ENORMOUS WING SPAN. (ESPENLAUB)

1.—SPOT LANDING CONTEST. (E. MEYER)

2.—ELABORATE INTERNAL TRUSSWORK OF A GLIDER WING



1.—GLIDER UNDER CONSTRUCTION AT AACHEN COLLEGE

2.—A GULL-LIKE DESIGN. (AACHEN)

1.—A FLEET OF TRAINING GLIDERS

2.—A TRAINING BIPLANE GLIDER

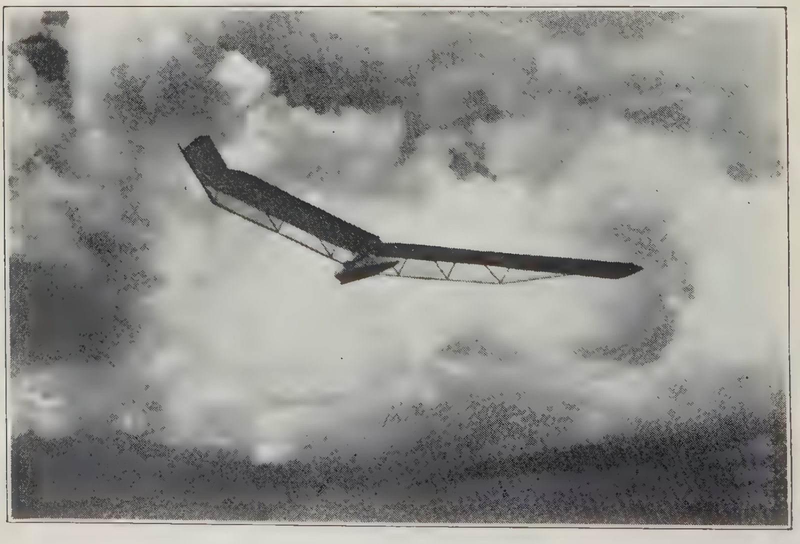
1.—CENTRAL LANDING SKI

2.—SPOT LANDING

1.—A TYPICAL LIGHT PLANE OF GLIDER DESCENT

2.—A "FLAPPER" EXPERIMENT. (ZEISE)

1.—WARPING WINGS. (HARTH)

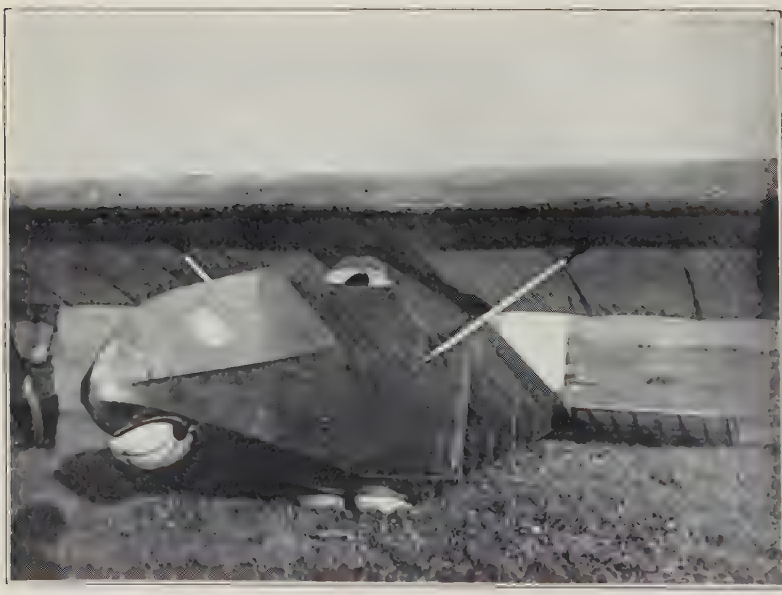


2.—TAILLESS GLIDER. (LEUSCH)

1.—WING-TIP BRAKES. (KOLLER)

2.—STARTING THE GLIDER. (DARMSTADT)

1.—ONE WAY OF HAULING THE GLIDER UP HILL



2.—ROTATABLE FOOTBALLS AS A LANDING GEAR. (HANOVER)

ANOTHER WAY OF HAULING THE GLIDER UP HILL

THE COMING OF THE NEW COAL AGE[1]

By Edwin E. Slosson

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[With 1 plate]

We stand at the opening of a new era in the utilization of coal, for here and now are being discussed as actual operations processes and projects which a few years ago were purely theoretical and commonly considered chimerical. In talking of the "old coal age" and the "new coal age" I am not referring to the Carboniferous period and the later deposits, for I am here concerned not with the formation of coal but with its consumption.

In the old coal age, which has lasted now some 600 years, we knew nothing better to do with coal than to burn it. But in the new coal age now opening we have found that coal can be put to better purposes than to be burnt in its crude state; that when we use it merely as a fuel we are losing compounds that may some time be worth more to the world than the heat obtained. We are beginning to realize the value of coal as a source of raw material for the synthetic chemist.

In 1306 King Edward I issued a proclamation making the use of coal as fuel in London a capital offense and one man was executed for the crime. Five hundred years later Col. George Shoemaker was threatened with arrest for attempting to sell a few wagonloads of coal in Philadelphia. When it was first proposed to burn coal by piecemeal, using the gas for lighting and then the coke for heating, the idea met with furious opposition. Scott, Byron, and Napoleon were among those who made fun of the crazy notion. A German paper in 1816 (Koelnische Zeitung, March 28) condemned the project of street lighting on six points: (1) Theological, as blasphemous, since God had divided the light from the darkness; (2) juridical, people should not be compelled to pay for gas they do not want; (3) medical, the emanations were injurious to health and people would stay out late and catch cold; (4) moral, the fear of darkness would vanish and crime would increase; (5) police,

[1] Reprinted by permission from Proceedings of the International Conference on Bituminous Coal, Nov. 15–18, 1926.

the street lights would frighten horses and embolden thieves; (6) economical, great sums would be sent to foreign countries.

The use of coal in locomotives and steamships was likewise condemned and ridiculed on the start. In 1804 the British Admiralty declared it their duty "to discourage the employment of steam vessels as * * * the introduction of steam vessels was calculated to strike a fatal blow to the naval supremacy of the Empire." Yet in spite of this warning from the highest authority the British Empire has somehow managed to survive the introduction of steam navigation.

We laugh at the people of 600 years ago because they thought that coal was not fit to burn. But will not the people of 600 years hence laugh at us because we thought that coal was fit for nothing but to burn? We look back with scorn to the time when efforts were made to prohibit or restrict the burning of coal as it is carried on to-day. But may we not look forward to the time when efforts will again be made to prohibit or restrict the burning of coal as it is carried on to-day? In fact, capital punishment has already been advocated, though in jest, for such a crime of wastefulness. The secretary of the British Royal Commission on Oil Fuel, Admiral Dumas, said not long ago:

> I would like to see a government official hanged at every lamp-post where gas is burned, because benzol goes up with the flame.

He had in mind the impending shortage of gasoline, for which benzol, otherwise known as benzene, is a suitable substitute as motor fuel.

President Baker is more sanguine, although less sanguinary, in his predictions, when he said in his opening address of the International Conference on Bituminous Coal:

> In less than a generation the present methods of shipping coal to be burned in its raw state under boilers hundreds of miles from the mines will appear to have been primitive and rudely unscientific.

The familiar phrase for anything particularly expensive or extravagant, "It costs like smoke," implies doubtless an unconscious realization of the fact that oxidation is the reversal of the synthetic reaction, the undoing of the constructive activity of animate nature. The plant builds. Man utilizes. Fire destroys. Now, one of the most wasteful forms of smoke was that which poured uninterruptedly during the great part of the last century from the open tops of the beehive coke ovens. In fact, one can yet see these prodigal flares on the Pennsylvania mountains as he looks out of his Pullman window in the night. Now, this is not merely a waste of fossil fuel, which we already begin to realize will not last forever, but there is also a loss of a variety of compounds that can be made very useful if

properly worked up. If a ton of bituminous coal is heated in a closed retort, instead of the open beehive, we may get besides the gas and the coke a dozen pounds of ammonium sulfate and a dozen gallons of tar. The ammonium sulfate is valuable for a fertilizer, since it will feed nitrogen to the crops, and the tar on redistillation will yield a dozen products out of which some 200,000 distinct organic compounds may be made, some of which are extremely useful to mankind.

The war has taught the United States a lesson in economizing the by-products of the distillation of coal. In 1913 nearly three-fourths of our coke was made in beehive ovens, which wasted the tar, ammonia, and light oils. In 1925 the ratio was reversed and more than three-fourths of our coke was made in ovens that saved these by-products. Last year was the peak in American coal-tar production, over 528,000,000 gallons; but 60 per cent of the tar so recovered was afterwards consumed as fuel instead of being worked up into chemical compounds. Tars can be easily and cheaply stripped of their phenols and cresols to supply domestic needs without materially reducing the fuel value of the tar. Yet the burning of untreated tar is on the increase in our country.

In the old days before the war when men wanted to get more gasoline than petroleum contained they knew no other way to get it than to smash up the big molecules into little ones, to break down the heavy oils to make light oils. This "cracking" process was regarded as a great achievement in its day, and quite rightly, since we could be running few automobiles without it. But the world is passing into another era now, the age of synthesis, when the chemist will build up instead of breaking down. Starting with the commonest and cheapest materials, air, water, and coal, the chemist can construct at will all sorts of valuable compounds for which we formerly had to rely upon nature, if indeed we could find them at all.

The veteran French chemist, Prof. Paul Sabatier, of Toulouse, opened the door to the new era with the key called "catalysis." Before the end of the last century he found that hydrogen gas could be made to unite with carbon-monoxide gas in the presence of finely divided nickel and produce methane, well known in natural gas. Now, these two constituents, hydrogen and carbon monoxide, are easily made by passing steam over red-hot coal, the "water-gas" process. Many other metals and compounds have since been found to act like nickel as a catalyst; that is, they speed up a process by their presence without being used up or appearing among the products.

The building blocks used by the synthetic chemist in this new game he is playing are mostly the four ordinary elements, carbon, hydrogen, oxygen, and nitrogen. We may combine their initials

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and call these constituents CHON for short. Nitrogen and oxygen have been impartially apportioned by Providence to every country in exact proportion to its area. Hydrogen may be obtained from water which heaven showers upon most lands in sufficient abundance. Carbon also is distributed equally and freely in the carbon dioxide of the atmosphere, but in such minute amount that we must employ the plants to collect it for us, especially those which lived in the Carboniferous period, when vegetation was more abundant and worked cheaper than it does to-day.

To effect the liquefaction of coal, all that is necessary is to add water to it. But this is not a problem in simple addition, like dissolving a lump of sugar in a cup of coffee. It involves linking up electrons, and usually heat, pressure, and a catalyst are needed to effect the union of the atoms.

What kind of chemical compounds might be made from the coal, air, and water? Obviously all the multifarious substances composed of these elements that exist in the three kingdoms of nature, animal, mineral, and vegetable. We have the same raw materials to work with as the plants and animals and the same source of energy, and we ought to be able to make anything that is made by any living creature if we only knew enough. But we can go much further and make hundreds of thousands of carbon compounds that never existed until they were invented in the laboratory.

It has recently been demonstrated to the surprise of the commercial world that methanol may be made from coal and water. Methanol is the same liquid as has hitherto been commonly known as "methyl alcohol" or "wood alcohol," but this name has been the cause of frequent and sometimes fatal confusion by those who think the alcohols are fit to drink. Ethyl alcohol looks very much like her smaller sister methyl, but the two can be distinguished by their physiological reaction on the human system. Ethyl may make a man blind drunk but methyl may make him drunk blind. Methanol in its proper place, which is outside the human stomach, is a useful article in many manufactures and some 8,000,000 gallons have been made in America annually by the distillation of wood. But this method of manufacture is now hard hit by a new and cheaper process developed in Germany, which uses water gas as the raw material.

Various other alcohols, such as butyl alcohol, made in America by fermenting corn, are made in Germany from water gas. Such liquids are finding a new and extensive field as solvents for the cellulose lacquers which are being used on automobiles and furniture. They are likely to displace in large part the paint and varnish which have been employed from time immemorial, since they can be either

sprayed or laid upon a surface; that is, applied either with the air brush or the hair brush.

The water gases that in some sections of the United States are still allowed to escape from coke ovens unused are at the mines of Bethune, France, cooled and condensed and utilized for making methane, benzene, ethyl alcohol, and ammonia.

Owing to the catalytic process for synthetic ammonia invented by Fritz Haber, Germany is now exporting fertilizer instead of importing it, as before the war. About 425,000 tons of free nitrogen from the air is now fixed for fertilizers by catalysis every year, and this takes the place of 2,700,000 tons of Chilean nitrate. But Muscle Shoals still stands idle.

Benzene, which can be be made from coal in various ways, is the mother substance of the aromatic family of chemical compounds, a family of over a hundred thousand and rapidly growing. Among these are the synthetic dyes and drugs that have made the world brighter and safer in our generation. One of these products, carbolic acid, is familiarly used as an antiseptic and is nearly as useful, though much less familiar, as one of the two components of bakelite. The other component, formaldehyde, is also an antiseptic and also made artificially. If such synthetic resins could be cheapened as much as General Patart foresees, they would be used for the finishing and furnishing of houses and find innumerable and inconceivable other applications.

The chief stimulus to such investigations in Europe is the search for homemade motor fuel. We Americans are not much interested in this question now, but some day we shall be, and meantime it is interesting to watch their chemists trying to see how many different things they can make out of common coal, like children playing with the Chinese tangram.

When kerosene first came into use as a lamp illuminant, it was called "coal oil," for it used to be supposed that petroleum had somehow been formed from coal. Later that theory was called in question, and geologists are still disputing the origin of oil. We seem likely to use it up before we find out where it came from. But even if coal oil turns out to have been an inappropriate name in the past, it may prove to be true in the future, for petroleum can be made from coal, and some day we may all have to make it that way.

For the less oil we have the more we use. The lower the supply in the ground the higher the output of our refineries. This increase in consumption can not keep up forever, however liberally you may estimate our unseen supply underground.

The countries that are short on petroleum are already contriving substitutes. The Germans, who were well supplied with coal but had little oil before the war, began experimenting on methods of making artificial petroleum. Since they have lost some of their best coal fields through the war and oil is harder to get than ever, they have been still more active in such research, and they have been amazingly successful of late.

Theoretically it is simple enough. Petroleum is a mixture of compounds of hydrogen and carbon. Just hitch up these two elements, and there you are! But there are other hitches in the proceedings. Either carbon or hydrogen will unite readily with oxygen, but they have little liking for each other. Only when stirred up by high heat and forced into contact by high pressure will they combine. Under these conditions the carbon and the hydrogen gas unite in all sorts of ways and form gaseous, liquid, and solid products of various usefulness.

The coal for this process does not have to be of a special quality, as is required in making gas or coke by our present methods. Any kind or form of coal can be used, and high yields of the hydrogenated products are said to be obtained from the brown coal and lignite of which the United States and many other countries have an abundance. Peat may thus be worked up to gasoline and other marketable compounds; also pitch, tar, sawdust, and any vegetable material.

When the first trolley car ran down the street of a southern city, an old negro watching the mysterious vehicle from the sidewalk was heard to remark:

> Dese Yankees is quah people. Fust dey come down heah and free de slaves; den dey come down and free de mule.

That is a good summary of the progress of civilization. The first animal that man enslaved was man. Next he shifted the burden in part to the back of the ox and the horse. Now human slavery is at an end and we are gradually getting to the point of releasing the lower animals from their enslavement. Eventually all the hard work of the world will be done by engines run by inorganic power.

Modern civilization is based upon such utilization of inanimate energy. The number of people who can live on the earth and the comfort in which they live depend upon how much energy can be obtained and how economically it may be employed. Of all conceivable sources of energy only the sun's rays are actually available and these not directly. Until some practicable solar engine is invented we must rely upon indirect means of making the sunshine work.

DR. FRIEDRICH BERGIUS, OF HEIDELBERG, INVENTOR OF A PROCESS FOR THE LIQUEFACTION OF COAL BY TREATMENT WITH HYDROGEN UNDER HIGH PRESSURE

(Photograph by Science Service, Washington)

The energy radiated by the sun reaches the earth through 92,000,000 miles of empty space as cold as can be. When the rays come into our atmosphere, they heat up the air and so set up currents in it. That gives us power for windmills. When the rays strike the sea, they heat up the water and evaporate some of it, which, carried away by the wind, falls on the mountains as rain. That gives us power for our water wheels. When the rays fall on a green leaf, they are set to making cellulose. That gives us fuel for our engines. There are then three ways in which to engage solar energy, two physical and the third chemical.

I suppose the first employment of external energy in the history of the world was when some prehistoric savage discovered that he could save himself walking by floating downstream astride of a log. Doubtless the second was when some other genius discovered that he could make the wind propel his log canoe across still water by hoisting a skin as a sail. The third method, the chemical process of using solar energy, came with the invention of the steam engine 150 years ago.

The chemical means of utilizing sun power, that is, combustion, is at present our chief dependence, but the little green leaves work too slowly for us. They can not keep up the pace that modern life demands. So we have drawn upon fossil fuel, upon the carbonaceous accumulations of the Paleozoic period. The iron horse feeds on subterranean pastures. We stoke our engines with the giant ferns and mosses that grew in Wales or Pennsylvania long before human life began.

In the green laboratories of the curious vegetation of that remote era, the light waves from the sun acted as they do to-day, dissolving in the plant the bonds that connected the carbon and restoring the oxygen to the air. We now reverse the process and reunite the carbon of the coal beds with the oxygen of the air and so revive the sunshine that fell upon the earth millions of years ago.

But we have for a century been living upon our carbonaceous capital. We have skimmed the cream of our coal beds and wasted about 99 per cent of its power. The concentrated fluid extract of fossil fuel, petroleum, is even more limited and has been still more recklessly wasted. Coal is scarce in many parts of the world and oil will soon be scarce everywhere. The Southern Hemisphere is conspicuously deficient in coal. Africa, South America, and Australia have not enough for their own needs and will have to borrow from their northern neighbors.

The most obvious distinction between plants and animals is that the former have roots and the latter have legs. Plants are mostly sessile; animals more or less mobile. Man, having only two legs and

being devoid of the wings of the birds and the caudal propeller of the fish, is at a natural disadvantage compared with the migratory members of the animal kingdom, but in the twentieth century he has surpassed them all and raised himself farthest above the vegetable stage. By the aid of his engines he can now outfly the eagle, outswim the fish, outpull the elephant, and outrun the deer. This new freedom he has employed unprecedently in tourist travel and mass migration.

The mobility of modern man is due to his tapping of subterranean stores of fossil fuel, coal and oil. The expansion of Europe is based upon the expansion of gases. The power of the peoples which now dominate the world in war and peace is the pressure of mutinous molecules released from bondage. Modern civilization is based upon atomic anarchy. This is the force that in war propels the cannon ball and explodes the shell and in peace pushes the piston of the steam engine and the automobile. Steam reigned undisputed for about a century, say, from 1776 to 1876. After that date came the internal-combustion engines, which were more efficient and compact, since they produced pressure by the explosion of their own fuel and needed no fire box or boiler, the Otto engine using gas in 1877, the Daimler engine using gasoline in 1892, and the Diesel engine using crude oil in 1897. These made possible in the twentieth century the airplane and the automobile, the motor boat and the motor cycle, the tractor and the tank, and gave to shop and farm a convenient motive power requiring no engineer or fireman.

The mobility of man is measured by the mobility of the power he employs. Consequently the efforts of technologists are now directed toward increasing the fluidity of fossil fuel; the finer the particles the more fluid the form. The cheapest and most abundant source of energy is coal, but this is solid and deeply embedded in the rocky matrix of the earth's crust. From this matrix the coal has to be torn lose by explosives and then broken into lumps small enough to be shipable and shovelable. By putting fuel into powdered form it can be blown into a furnace on a blast of air. But combining it with hydrogen we can reduce the carbon to a liquid form and by heat convert it into a gaseous state where all the molecules are free and independent.

But the atom is not the limit of divisibility, although that is what its name implies. As we now know, it is possible to break up the atom, and its finer fragments, electrons and protons, afford us a still more fluid form of energy, the electrical current. To transport solid coal from mine to the factory requires a large part of its power. To transport water from the mountain to sea requires no power. It will flow downhill of its own accord if you will only provide it with

a sloping channel or an empty pipe. To transport electricity from a point of high potential to a point of low potential requires no power. The current will flow downhill of its own accord if you will only provide it with what is for it an empty pipe, that is, a copper wire. And the electric current will travel far faster than the coal train or the flowing stream. So the efforts of inventors are now concentrated on methods of increasing the mobility of energy by such means as converting coal into a liquid form, or converting its energy into the electrical fluid.

The greatest scientific achivement of the nineteenth century, in the opinion of those who lived in that century, was the formulation of two fundamental physical laws of the universe, the conservation of mass and the conservation of energy. According to these, matter and energy were immutable in amount and neither could ever be created or destroyed in the minutest measure.

But the twentieth is an unsettling century. Such mental revolutionists as Einstein, Planck, and Bohr have opened our eyes and widened our outlook. We can not be so cocksure about many ideas as were the simple-minded scientists of the former century. Some of the generalizations which seemed to them absolute and universal principles of nature appear to the more critical eyesight of the present generation to be disguised definitions, similar, as Eddington puts it, to the Great Law to which there is no exception, that there are 3 feet in every yard.

For instance, the law of the conservation of energy. We see a lump of burning coal giving off energy at a great rate as radiant heat and light. Where did that energy come from? Where was it when the lump was cold, if no energy can be created in the course of combustion? The reply of the nineteenth-century chemist was clear and decided. The energy was there all the time in exactly the same amount, although its presence could not be demonstrated, because it was in the form of "potential energy." Obviously this was unanswerable as an argument, although not very enlightening as an explanation. We are nowadays disposed to suspect that this "potential energy" was put into the coal by logic rather than by geology, and that if it exists in nature at all it is in the nature of the human mind. The twin laws of the conservation of matter and energy are as useful as ever, for they still serve to clarify our conceptions and to guide our experimentation. No experiment has ever been able to detect the slightest flaw in them, and it may never be possible to devise tests so delicate as to disclose any discrepancy. Yet neither law is now regarded as absolute in itself, and it seems that we shall have to substitute some general law which will include the two and allow for the transformation of matter into energy and vice versa. Ein-

stein has worked out the formula for the equivalence of matter and energy, so we can now calculate how much heat will be produced if a certain mass of matter is annihilated. This idea has been welcomed by the astronomers, who have been hard put to it to devise means of keeping up the furnace fires of the sun as long as mankind would like to live. They have now figured out by Einstein's formula that the sun is losing weight, through the destruction of its material and the emission of immaterial energy, at the rate of 4,000,000 tons a second. But even though wasting away at this appalling rate the sun can hold out for 10,000,000 million years.[2] This gives a welcome extension of time for the life of our world and permits us to hope that we may get our social system perfected before we all become Eskimos.

This principle of the interchangeability of matter and energy must apply to all chemical reactions where heat is produced or absorbed. Wherever coal burns there matter is being converted into radiant energy. Wherever a green leaf grows there matter is being manufactured out of solar energy. In such cases of course the quantity of matter or energy transmuted is too small to be demonstrated. In the burning of coal the heat evolved means a loss of about 1 part in 10,000,000,000 of the joint mass of the carbon and oxygen combined. But this loss of matter becomes appreciable when we consider the world-wide consumption of coal. If we assume that all coal is pure carbon and that the combustion is always complete, the carbon dioxide produced by all the coal that burned in a year throughout the world would weigh about 5,000,000,000 tons. This would involve a disappearance of matter amounting to half a ton. The substance of the world is therefore being slowly consumed by the combustion of coal. But such loss is continually being replenished by the sunshine that falls upon vegetation and is there fixed in the form of cellulose.

The problems we are considering are world-wide questions in which the whole human race is concerned, for they deal with the subterranean stores of wealth-producing energy which are the common inheritance of the population of the planet. These treasures are limited and irreplaceable, and upon them our modern civilization is supported. The main question, and the only one with which science as such is concerned, is to see that this endowment of fossil fuel is not wasted but utilized to the greatest advantage of the present generation and posterity. Who owns it, and who makes the most money out of it, are minor matters that do not affect the main question. Germany lost a large part of her coal trade through the world war. England lost a large part of her coal trade through the labor war. But neither of these affects directly the coal that is

[2] Heyl, Fundamental Concepts of Physics, p. 72.

still in the ground. Coal is coal whether it is dug by Germans, British, or Frenchmen, or as in the case of American mines, by all the races of Europe working together.

The nation that deserves the most credit is that which makes best use of its share of fossil fuel, and making the best use of it does not mean using it up fastest. We owe a duty to posterity, and we condemn a spendthrift father who dissipates his fortune and leaves his son destitute. When we learn that 60 per cent of the coal tar produced in the United States is burned for fuel, we feel that something is wrong, but we do not know how to remedy it. We can not compel a man to save by-products that he can not sell or to work land that does not pay. The frequent admonition of a mother to her child at table, "Eat your crust; some day you may be starving and be glad to get it," is not convincing. The normal child can not conceive of ever being hungry enough to eat that crust, and he can not see how eating the crust now would provide it for him on that hypothetical day of destitution. We can not store up unusable stuff for an indefinite future nor refuse to make use of our buried treasure for the present needs on the ground that our grandchildren may make more out of it.

There is no world organization that can exercise the right of eminent domain over natural resources and compel a country to stop wasting its coal and oil or to employ its unused land and water power. But all the same, and all the more, we should all rejoice when anyone discovers how to make a profit out of a waste product or how to make a process more efficient. When a way is found to convert a low-grade lignite into a high-class motor fuel, or to make manufactured alcohols and acids of the gas that used to flare from the tops of blast furnaces, or to clear the air of our industrial towns, or to raise the efficiency of a fuel by low-temperature carbonization, he has thereby benefited the human race, living and to come, whether he makes money out of his patent or not. All knowledge goes ultimately into a common pool from which every man may draw what he can use. Pure science is essentially international, however it may be nationally applied.

IS THE EARTH GROWING OLD?[1]

By Josef Felix Pompeckj

When geology treats of the age of the earth, it bears in mind only a portion, indeed only a very modest fraction of the period of the earth's existence. This relates to the time taken for the formation of only the outer shell of the whole earth's globe, where there lies the possibility of geological exploration.

For the evaluation of that length of time which elapsed from the very beginning of this earth to its present state we have no certain basis, no sufficiently sure means for estimations. The confines of the universe provide no further help than such as can be gained relative to the hypothetical evolution of the stars based upon the phenomena of the meteors, the planets, the suns, and the varied forms of the nebulæ. Though such ideas rest upon physical laws, nevertheless they are purely hypothetical. The length of time for observation by mankind, so far elapsed, has not been sufficient for us to have convincing observations as to the development of a star. Even the "novæ" give us no clue; in their short life of brilliancy we gain knowledge only of an all too short catastrophic episode in the life of a giant star, knowing nothing of the star's life previous to the catastrophy.

Whatever hypothesis as to the development of the earth we keep in the foreground for the following details, the history of the earth, in point of time, begins with the moment recorded for us by the oldest observed rocks.

What we know of the rocks of this outer layer of the earth—with the exception of relatively few and quantitatively trivial samples from the bottom of the oceans—relates only to the continents and islands. In comparison with the earth's whole bulk, these rocks are an extraordinarily small portion.

We can penetrate into the earth's crust only a little over $2\frac{1}{4}$ kilometers, about one two-thousand-and-eight-hundredths of the

[1] A discourse (introductory paragraphs omitted) delivered in the new hall of the Royal Frederick-William University, Berlin, by the rector on Aug. 3, 1926, at the celebration held in memory of its founder. Translated and published by permission.

earth's radius. This is in the deepest boring, that of Czuchow,[2] in upper Silesia, driven by the Prussian Government, purely for the solution of important scientific questions. However, the crust fortunately does not cover the earth as a homogeneous layer. It is broken up endlessly into fragments. The separate pieces are multifariously and greatly piled upon and against one another. Great masses are often folded and thrust into the most complicated patterns. Therewith is offered to us the possibility of gaining an insight into a considerably greater depth of the earth's crust. Take, for example, northwest Germany. Despite the slight differences in the altitude of this region, because of the juxtaposition of portions of the earth's crust belonging to very different geological formations and ages, we can here inspect an equivalent thickness of 12 kilometers of sedimentary rocks, dating from the Devonian to the end of the Cretaceous.

American geologists estimate the possibility of thus gaining an insight down to a depth of 100 or more kilometers of the earth's crust. This is surely too large an estimate. It results from a summation of the greatest depths estimated from rocks occurring in separate regions. The addition of such maximum magnitudes gives us a false picture, since in the different regions of the earth, in the same geological epoch, under differing geological conditions, quite different thicknesses of rocks may have been formed. A depth of 30 kilometers is hardly too small an estimate for the depth of the rocks belonging to all the known strata of the earth. Here we consider primarily the layers of sedimentary rocks—sandstones, limestones, etc.—which occur in numerous modifications due to the action of the atmosphere, water, ice, wind, organic life, and which form the unique evidences of the earth's history.[3] But nowhere is this documentary rock book, making up our knowledge of the earth's history, complete throughout the 30, or let us say 100 kilometers. Nowhere at the surface of the globe have there occurred continuously throughout time the formation and conservation of these stratified rocks.

The first rock of sedimentary nature could be formed upon the earth only when there was already a solid substratum upon which and from which sedimentation was made possible. The examination of the oldest and deepest known rocks—those of the Archean age—shows the simultaneous occurrence of sedimentary as well as igneous rocks. The latter exist in such relationship to the sedimentary ones that it is indeed impossible that out of these solidified masses the first

[2] Czuchow, which was the deepest German and Old World boring, has been surpassed by the boring of Prickett's Creek, W. Va., reaching a depth of some 40 meters more than Czuchow.

[3] F. W. Clarke has computed that the mass of all the sedimentary deposits is sufficient, if spread in a layer over the whole earth's surface, to cover the earth only to a depth of 800 meters, if we take in consideration a thickness of the earth's crust of 16 kilometers.

substratum could have been formed upon which was laid the first sedimentary stratum. By the manner and means of its occurrence, one type of rocks always requires the existence of the other. It is therefore impossible that the oldest known rocks were the first formed.

Now let us postulate, instead of the more generally known Kant-Laplace hypothesis, the Chamberlin-Moulton planetesimal theory. The latter surely more readily explains many phenomena of the solar planetary system than does the older hypothesis. With Chamberlin and Moulton we see the earth increasing in mass through the accretion of those small cosmic bodies, the planetessimals. The earth is thus increasing even at the present, although, indeed, in comparatively small amount, through its encounters with meteors and shooting stars.[4] According to Chamberlin the earth could support organic life by the time it had reached the diameter of Mars; that is, with a volume of only one-ninth of its present amount. Be that so, the earth, in order to sustain life, must then already have had a rocky crust and pressing upon this a hydrosphere and an atmosphere. The formation of sediments would then have taken place, and since that time the earth's crust, in round numbers, must have increased in thickness some 3,000 kilometers. How very decidedly thin is the earth's shell, which we know, in comparison with this great thickness!

Compared with the great size of the earth itself, that part of its crust which is known to us is indeed very petty and the lapse of time necessary for its formation surely vanishingly small compared with the eons which have passed since the birth of the globe itself.

Since the arbitrary appraising of the complete age of the earth by Buffon, now more than 150 years ago, as 74,600 years, repeated researches have been undertaken to evaluate the lapse of time required not only for the formation of the earth's crust but also for the formation of the various rock strata which make up that crust. The various estimates differ greatly. The various premises lead to divergent results.

Figures for the length of time which must have elapsed to account for the formation and accumulation of the sedimentary deposits known within the earth's crust have been obtained from the abrasive effects of the surface waters, from the amount of the newly accumulated sediments, and from the extent of the geological changes at the earth's surface. The resulting values for

[4] An unpublished computation made by my esteemed friend, E. A. Wuelfing, indicates a total of some 3,650,000,000 shooting stars which the earth annually encounters. Their mass could easily amount to a respectable number of tons.

the absolute age of the sediments within the earth's crust vary greatly among themselves, from 30 up to 400 million years.[5] This should not be surprising, for if to-day the rate of formation of sedimentary matter varies greatly in different localities so it must have been in the past. It is, moreover, difficult in the estimation of the lapse of time to make satisfactory premises.

It is an undoubtable supposition that the salt content of the oceans originates from the rocks of the continents (the last end of volcanic activity) and that this salt was carried by the fresh water of the land into the oceans, increasing their salinity; from estimates of the rate of import and deposition we can determine the lapse of time for the existence of the oceans, at least since pre-Cambrian times, and therewith the ages of the sediments in the sea regions of past ages. Values of 100,000,000 to 340,000,000 years have thus been reached.[6]

Apparently very trustworthy estimations of the lengths of smaller durations of time in geological history have been recently made.

The water melting from the inland Scandinavian ice has resulted in the formation of the so-called Bändertone. De Geer recognizes in these, in their alternation of fine sand and clayey material, the influence of yearly variations in the rate of melting of the ice, whence, for the Scandinavian peninsula, he has computed the time elapsing from the beginning of the retreat of the diluvial ice until the present as 12,000 years. Sörgel saw in the rock sequences of the Thuringian diluvium the decisive influence of cosmic factors, the cyclical variation in the obliquity of the ecliptic, the eccentricity of the earth's orbit, as well as the variation of the perihelion distance of the earth and the variation in the intensity in the sun's heat dependent upon these. From these he placed the beginning of the north German diluvium more than 580,000 years ago.

The physical chemists consider that the surest method of estimating the ages of rocks depends upon the amount of the radioactive transformation products present, due to the passage from uranium and thorium to lead and helium, respectively, in the minerals of volcanic origin. The basis for this surety is the fact that radioactive processes are wholly independent of surrounding chemical and physical conditions and pursue their transformations slowly indeed, but at the same speed for all time. Using the rate of transformation of uranium or thorium, the absolute age of a number of volcanic rocks, differing in geological periods, has been computed. Although the values obtained are not fully concordant, generally the results are

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[5] We quote only a few values: Sollas reckoned 34,000,000 to 80,000,000; Phillips, 38,000,000 to 96,000,000; Walcott, 55,000,000 to 70,000,000; de Lapparent, 67,000,000 to 90,000,000; Geike, 100,000,000 to 400,000,000 years. Ami Boué sometime since published a very complete summary of the older estimates.

[6] New estimates due to Sollas give 100,000,000 to 175,000,000; to Holmes, 210,000,000 to 340,000,000; and to Schmiedel of at least 300,000,000 years.

of the same order of magnitude, and large. For the duration of the diluvium about 1.5 million years was computed. Uranium minerals from the Carboniferous age indicate a lapse of 335 million years and rocks from the pre-Cambrian, the period wherein there is direct evidence of a rich and already much differentiated organic life, a lapse of 1,000 to 1,600 million years.[7] [8]

The values obtained in this manner exceed from fourfold to much more those obtained from other geological methods. They are, indeed, very much greater than most estimates based upon the Kant-Laplace hypothesis as connected with the cooling of the earth from a molten condition to its present temperature. Whether it is possible that a more thorough knowledge of the course and duration of the radioactive processes may reduce the age values deduced from such processes—and Joly has already raised objections against the very high values won through the uranium-lead reactions—or the values obtained from geological evidence come nearer the truth, one thing remains certain: The scanty section of the earth's body, which we know geologically, is old. Gradually we have regained our lost respect for great values. Even the approximately 300,000,000 to 400,000,000 years, which is indicated by the salt method applied to the sedimentation within the earth's surface layers, suffice for the indication of a very high figure for the age of these layers known. However, we must assert very strongly that we are far from able by geological means to set the time of the beginning of the formation of the crust of this earth. Evidently the complete time for the existence of the earth must be very manyfold that of the geologically determined period of the earth's history.[9]

Is this earth, whose age is so many millions of years, as thus read from the rocks within its crust, really growing senile?

And this riddle is well asked. We speak of the stars as growing old along the sequence from the white stars to the yellow, from the yellow to the red; the moon is believed to have rapidly aged and died; the cosmos presses on to a warm death; life on this globe presses on to a cold death.

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[7] How widely the estimates of ages from the uranium and thorium minerals may vary is indicated by the work of L. A. Collins (Amer. Jour. Sci., 5th series, vol. 12, July, 1926). The following ages for pre-Cambrian minerals of Australia were estimated: For a fergusonite, 620; a mackintoshite, 1,475; a pilbarite, about 3,840 million years. However, the last-named mineral is annotated as "altered," so that within it the lead-uranium relationship should not be normal but the range from 620 up to 1,475 million years does not seem very small.

[8] The late Professor Barrell (Bull. Geol. Soc. of Amer., vol. 28, 1917) estimated the time since the beginning of the Cambrian period at 700,000,000 years, basing his conclusions mainly on radioactive data. (Translator's note.)

[9] Nernst, arguing generally from the Kant-Laplace theory, estimates the period of the earth's existence as a hot liquid ball as equivalent to the length of time which has elapsed since the formation of the earth's crust, as obtained from the earliest uranium minerals, i. e., about 1,500 million years.

Yet what shall we understand as the aging of this earth? Where and how will this aging be expressed?

Shall we carry over to the earth without further qualification the physiological ideas and processes of growing old, which in many instances are not exactly qualified or known? May we apply such ideas to an inorganic body like the earth?

Evidently the earth, in its processes, presents no picture of developments equal to organic developments.

The biological changes in the life processes of an organism are bound with the wonderful protoplasm through the highly specialized phenomena of assimilation, dissimilation, organic growth, and reproduction.

The petrologist in discussing the earth's volcanic rocks may indeed speak of magmatic "assimilation"; but the inorganic "assimilation" in the earth's crust, in the earth's body, is nothing more than a "solution" within the molten mass through the addition of a foreign substance within an existing molten substance. Similarly magmatic "differentiation" is not to be compared with organic "dissimilation." It is nothing more than one of the various reactions between the components of the magma according to their relative quantities and relations to each other and the variations in the pressure and temperature of the surroundings.

Though, following the planetesimal theory, we talk of the earth growing to its present size, yet this growth is not taken in the sense of the growth of an organism through the actions and reactions of the latter's protoplasm. The growth of the earth is to be taken merely as a simple increase in bulk through the accretion of cosmic bodies. There was, and is yet to-day, an assimilation of these bodies into the earth's substance through weathering and various transformations; but there is here only an addition to the earth of matter, similar to the substance of the earth, coming to it from outside space.

If we might speak of the moon, as W. H. Pickering expresses it, as a late-born child of the earth, and if the depths of the Pacific Ocean indeed show the womb from which the moon was torn out of mother earth's body, this process of the division of a heavenly body into two is least of all to be taken as an instance of organic reproduction.

In general what then shall we take as an expression of the life of the earth that we may measure its growing old? The life of an organism is bound up with protoplasm and its motion. With what is the life of the earth bound? Neither its existence nor yet its length of existence is to be taken as the sense of its life. If we are to draw a parallel from the life of the organic world, then the life of a star

should be evidenced by the changes which occur within it through the motions of its component masses. For the earth this will mean to us alterations through movements of masses upon and within the earth's crust, the evidence for which is documented in the manner and nature in which the rocks of the earth's crust occur.

The mass movements of the earth's crust are manifold. There are the movements of the atmosphere and the hydrosphere and their effects upon the rocks of the earth's surface through weathering, chemical transformations, mechanical transportation, the accumulation of material, the formation of new rocks, the movements of glaciers with their effects upon the earth's surface, etc. The intermixing of the rocks of the lithosphere occurs in great variety—through faulting, the earth's crust breaks into great blocks some of which rise, some sink; through folding, the massive mountains and mountain chains rise between immobile blocks; through warping, the earth's crust is arched up in some places, in others it is depressed. The seas accompany such movements by invading the lands in places and in turn are forced to retreat. Paroxysms of trembling in the earth's crust occurring as earthquakes, and the mad outbursts of volcanoes are bound up with movements of the great blocks of this crust. Finally there are the slight tidal movements within the crust, the tides of the ocean and the slight, restless movement of the earth's axis of rotation. All these movements may be taken as the expression of the life of the earth, that Berget has attractively sketched in his beautiful book, "Life and death of this globe."

An organic body (organism), by virtue of its construction out of protoplasm, possesses the ability to pass through its life processes; but this ability is active only when its protoplasmic cell exists in the proper relations to light and warmth, to water and air, and with the necessary food supply. Similarly at least a very great part of the expression of earth-life is possible only through the determining interaction of its surroundings and the cooperation of cosmical influences. Over all stands the mastery of the eternal laws of cosmical physics.

The motions of the atmosphere and the hydrosphere are developed, widely influenced, and kept in their courses through the cosmical element of the radiation from the sun, the earth's rotation, and the changing position of the earth in its orbit. In their motions, as well as their actions upon the rocks of the earth's crust, the atmosphere and hydrosphere are greatly directed and influenced by the action of gravity. Therewith there is a striving, though often interrupted, within the earth's crust, and indeed throughout the whole earth, toward a position of gravitative equilibrium. The rocks formed under the action of the hydrosphere and atmosphere through the

transformation of preexisting rocks of the earth's crust, and the repeated overlaying of these upon other regions, alter the local gravitational proportion. Therewith result gravitational readjustments of far-reaching effects. The increased local loading through the heaping up of newly formed rocks creates in that region a subsiding movement beneath which there ensues a compensating sideways thrust. The thrust results in an upward movement of the earth's crust elsewhere. Movements of the earth's crust in one place set in action other readjusting movements elsewhere. These readjustments of the earth's outer shell are more or less bound up with the paroxysms of earthquakes and of volcanic actions. And the volcanic reactions continually make rise new masses from the depths to the earth's surface for the geological action of the atmosphere, water, ice, and organic life in a new cycle.

The building of the long, lofty mountain chains stands in close relationship with the mass movements ensuing from the action of the hydrosphere and the atmosphere. In the uplifted mountain chains, their altitude when rightly oriented relative to prevailing winds richly loaded with moisture results in a great increase of rain. Further the surface offered to weathering is much greater than on a level plain. Because of the increased altitude and consequently increased fall for the water, the movement of waters in their channels is greatly increased, and the latter's carrying power is much augmented. In the neighboring plains, where the movement and consequently transporting power of the water is much diminished, the decomposition products, due to weathering and abrasion, will be heaped up. In gathering places, in geosynclines, this mass of matter thus dragged down from the higher ranges upon sinking sedimentation plains, serves for the formation of thousands of meters of new rocks. Out of these areas, as earth history repeatedly shows, new mountains come into existence while the former highlands are worn in proportion to the abrasive action of the water.

None of these mass movements of the earth's crust occurs and works independently. All these life expressions interlock with each other. They show themselves in the most complicated interrelationships. In all these complicated occurrences, their continual, pulsating work forms the manifested whole of this earth's life, the changing episodes of which the rock-made archives of the earth preserve.

Though the unity and heterogeneity of this earth's life stands clearly before us, the next consideration is veiled in uncertainty: What is the unique actuating impulse which leads to this whole interacting complex of the life-assertions of this earth? What originates the impulse which gives to the earth's body the movements which constitute its life?

The answer seemed simple in the period of the unlimited sway of the laws of Kant and Laplace. The loss of heat by the earth entailed a shrinking of its body; this led through the crumpling movements in the relatively solid shell to a distinction between high and low, between mountains and lowlands. Herein lay the cause of all the complexity of the movements to which the earth's crust bears witness.

An especially fortunate form of reply at one time seemed to have been given, an enlightening explanation of the origin of the high and low places on the earth from which would follow necessarily all those movements which we are considering as the life of the earth. This reply came from Lowthian Green in his happy thought of the tetrahedral remodeling of the spheroidal earth. The corners and the edges of this tetrahedral earth were, as this illuminating theory explained, the necessary high regions which caused, directed, and influenced the movements upon and within the earth's crust. But unfortunately all too numerous and weighty objections can be brought against a theory based upon a loss of heat and the consequent contraction, as well as against one consequent to the laws of the nebular hypothesis relating to the contraction of the earth's crust, especially as connected with the reactions of a hot interior upon the outer crust. Such theories can not be brought into general recognition. Just as there are great objections to the nebular hypothesis in elucidating the relations within the planetary system, so there are to it for the explanation of the movements which constitute the earth's life-history.

In our need for an explanation of these events in the developments observed in the earth's crust we readily, perhaps too readily, resort to the phenomena of radioactivity. Out of the energy released from the radioactive processes we could conceive a simple explanation of the phenomena of the earth's life. Are we right in this?

However, it seems that at present we must rest content with our knowledge of these phenomena of the earth's life, their interrelationships, alternations, and sequences.

And now let us get back to to-day's question: Is the earth growing old?

Out of the 400 to 1,600 million years of the earth's history of which we know something, can we detect such changes in the evidence of the earth's life as would lead us to the conclusion that there is a crippling in these activities? Such a crippling would mean "growing old."

So far as the rock records of the earth are legible, the "actuality" principle, enunciated by Hutton and more fundamentally stated by Hoff and Lyell, holds for the processes within the earth's crust

throughout all the time of the history of the earth known to us. This principle, which has influenced the thoughts of geologists for nearly 100 years, is taken to hold now only in the sense that never upon the earth's crust have forces been active other than those which are acting at present.

Indeed even the oldest known series of rocks tell us, as do those of to-day, of the chemical and physical weathering of the previously existing rocks, of the transport of the weathering products by water and wind. They tell of the accumulation of these products in the lowlands which then existed in opposition to the highlands. They indicate an atmosphere and a hydrosphere with their movements and as to-day, also, the influence of the cosmical agency in the radiation from the sun. From the manner of juxtaposition of even the oldest known rocks there may be inferred the breaking of the earth's crust into huge blocks and mountain building movements of the same nature as those of later periods, just as in the more recent periods, glowing liquid from the depths was pressed through and out of the earth's crust. In one detail only does the evidence of the earth's earlier life differ from that of the present: The evidence of organic life is not handed down to us in the same manner as it is from later periods. That organic life did exist in the Archeozoic era the presence of lime and carbonaceous deposits demonstrates. But the Archaic life was less developed than in subsequent times and consequently its influence in the building and transformation of rocks was of less importance than later.

Always, throughout all time, the same forces, the same manifestations of the life of our earth have been at work as to-day. But not always have they had the same relative importance. Even to-day they do not work the same in all places nor at the same time. Weathering and denudation are much greater in mountainous regions, in the Alps, for instance, than in the flat lowlands in the north of Germany or on the wide plains of central Russia. Weathering and denudation work quite differently under different climatic conditions, as, for instance, upon the east and west sides of the South American Andes. The accumulation and transport of weathered rock is greater in mountain valleys and on the declivities of high peaks than upon the same base in the plains. The action of glaciers is limited geographically, topographically, and by climatic conditions to certain regions. The motions of the earth's crust through earthquakes and volcanic disturbances occur in some regions very much more than in others. In the same places the destructive and constructive forces change even now with the season and climatic changes.

The same conditions held in the past. The nature and amounts of movements and the results varied at the same time in different re-

gions. The differing composition of rocks formed contemporaneously in different regions shows this as well as the varying amounts of the existing rocks formed in the same time at different places. In the same region the formation of rocks varies in time sequence; that is, the factors leading to the accumulation of rocks have varied in intensity and action in the course of time. In the sequence of the rocks of the earth's crust we find almost endlessly occurring cyclic or rhythmic variations. Some of them are directly the consequences of movements in the scaffolding of the earth as shown in the rock series conditioned by the transgression and regression of the seas. Others document the influences of the rhythmical climatic variations which are in their turn bound up with the motions of the earth's crust. W. Ramsay was able to show this convincingly in his fine study, "Orogenesis and climate."

Rhythms are the most evident, the most striking features found in the developments of the earth's history.

The great massive upheavals of the earth's crust like that of the Scandinavian Peninsula, the subsidings like that of the bottom of France, occur rhythmically. They allow the sea to flood the land and then to recede. The repeated alternations of sea and land are rhythmical. The formation of mountain chains by the foldings of the earth's crust is rhythmical. Volcanic activity occurs rhythmically. The great ice ages of the earth occurred rhythmically and were differentiated rhythmically among themselves.

Rhythm dominates the onward flow of the earth's history; never was there uniformity in its paces.

Do these geological rhythms reoccur at equal lapses of time, or are the intervals becoming longer between rhythms of the same class? Are the expressions of the separate acmes becoming weaker? Is there any increasing insensitiveness of the earth to the actuating forces offering an evidence of old age?

Let us consider the formation of mountain chains through folding.

In the oldest period of the earth's history known to us there is such a widespread folding of the earth's crust known that it is indeed ubiquitous. It amounts to a general wrinkling of the earth's surface. Although it is impossible with any success to apply the methods of geology to determining the times of relative occurrence of the rocks of the Archaic times in regions separated from each other, we can at least conclude from the discordances between the Archaic rock series that the formation of the foldings of that era did not owe their existence either to a temporary process or one general throughout that period. For the subsequent foldings of the Algonkian era, although even here the comparisons are yet uncertain, we can say

that in both time and place the foldings are conformable. Then there come three great foldings, well recognized in time, place, and nature, the Caledonian, the Variscian, and the Alpidian. Each one of these three is not—as was assumed in the older interpretations—geologically speaking, the work of one time; rather each one is the result of a great number of different folding phases, which among themselves and at different places were of differing intensities and were separated by periods of relative rest so far as faulting goes. We owe to Stille a striking comparison of the occurrence of separate rhythms, the localities of which are very restricted upon small mobile zones of the earth's surface; in general these places are altered for each rhythm, showing the improbability of a really ubiquitous occurrence of the Archaic foldings.

Expressing the times of the occurence of these mountain formations in customary geological nomenclature, the youngest, the Alpidian, lasted with its 11 or 13 phases and their subphases, from the beginning of the Triassic to the end of the Tertiary, through no particular length of geological time. There is a strengthening of its phases until the older Tertiary and subsequently a decline. In the principal phases the folding was extraordinarily strong. The quiescent periods increased in length toward the Tertiary and then decreased in the more recent Tertiary. From its predecessor, the Variscian folding, it was separated by the geologically short quiescent period of the Triassic and in some places by the upper Dyas and the Triassic.

The Variscian folding period, with its four or five phases, occurred during the Carboniferous age and far into the Dyas, and in certain regions, to the end of it. Its phases, varying greatly in intensity in different regions, are separated from each other, so far as the sedimentation indicates, by relatively long periods of rest from faulting.

The Caledonian folding period was separated from the Variscian by the Devonian age, which saw no folding of notable intensity. In this period there are only two folding phases recognizable, separated by almost the whole Silurian. The later, the true Caledonian folding, was the stronger and the wider spread. The long period of quiescence of the Cambrian and the lower Silurian separates the Caledonian folding from those of the pre-Cambrian, the Algonkian and the Archaic times, which are to be placed in no definite comparable relation with the three later periods.

No geological evidence known up to the present gives a basis for the assumption that the time intervals between the three periods of folding should be increased. The number of folding phases in the three periods increases and the intervening intervals shorten rather than lengthen from period to period.

The intensity of the folding, neglecting the wholly undetermined relations of the Archaic-Algonkian times, has certainly not decreased; it has rather increased. It is difficult to reconstruct the mountains of the remote past out of the worn-down remains and then to estimate the magnitudes of the corresponding foldings. We do indeed have many pictures of highly complicated foldings, in the broader significance of the term, in the Caledonian of Scotland and Scandinavia and in the Variscian Appalachians of North America, but it seems to me idle to look in our Variscian Rhenish mountains for such foldings, for example, as the Simplon Tunnel has revealed in the structure of the Alps. The Variscian foldings in middle Europe were manifested upon a far broader basis than in our Alps. I gather from them the impression that on the whole they are less complicated than the more recent Alpidian.

The Alpidian folding occurred over world-wide areas. Its extent was certainly not less than the Variscian; it is known to be greater than the Caledonian folding.

All of this leads me to the conclusion that the possibility and the intensity of these movements of the earth's crust in the mobile zone or in zones which may become mobile and whence mountains may be born, are certainly not decreasing. In the processes of folding there is nothing that indicates that the earth is becoming senile.

During the geological present the earth is again in a relatively quiet period. The continental blocks stand under the influence of a geocratic period such as once followed the Variscian folding in Western Europe during the upper Carboniferous, the Dyas, and the Triassic. Under the still effective influence of the Alpidian folding, the neighboring regions are subjected to such climatic factors that the movements and geological action of the hydrosphere are still very intensive. The amount of these actions will be quite different when these young mountains have been more and more worn down; for instance, the regional climatic differences will be equalized throughout middle Europe. There will then be a repetition of the picture which prevailed at first in the quiescent periods of the Triassic and the Jurassic. However, it will be only the expression of a temporary mode, not a senile weakening of the atmospheric powers.

Since not confirmed by any geological evidence, the idea has been long given up of a steady decrease of the temperature of the earth from early times until the present, although it influenced geological thought for a long time. The demonstration of early ice ages in the Dyas, in the Devonian, in the pre-Cambrian, forces us to discard it because of the proof by Sartorious von Waltershausen, now three-quarters of a century old, that a rock crust at the earth's surface of only 3 kilometers thickness practically makes the temperature of the

earth's surface independent of that within. The temperature of the earth's surface has in no way become permanently lower; instead it shows rythmical changes. The great ice ages of the earth's history stand in close relationship with mountain ranges brought into existence through foldings. For the Dyas and the Diluvian ice periods, at least, the dependence is clear. Apart from orographic and cosmical causes the rhythms of the temperature depend upon the rhythmical feeding into the atmosphere of carbon dioxide of volcanic origin as well as upon the varying need of this gas in the formation of coal and the carbonate rocks. Arrhenius and Frech have noted the rhythm of these carbon-dioxide periods and shown their geological importance. To-day, through the consumption of the coal beds by man in his industries, a new enrichment of the atmosphere with carbon-dioxide is taking place. He also thereby wards off the remote danger of the death of the earth through cold.[10] From the earth we read no sign of danger that the oceans and rivers may become solid ice nor that carbon-dioxide snow will fall, nor yet that the earth, at a temperature of absolute zero, will be covered by a new ocean of liquid oxygen and liquid nitrogen, while only hydrogen and helium will form the last tenuous atmosphere of the dead earth.

The natural deliverer of this incomparably important breath of life constituted by the carbon dioxide of the atmosphere, together with the rich store of the gas dissolved in the waters of the oceans, is vulcanism. Besides the seismical tremblings of the earth's crust volcanic actions give us the most immediate evidence of the earth's life. Their manifestations, the movements of the glowing liquid masses toward the earth's surface, together with the accompanying and subsequent phenomena, are recorded throughout all geological time. They do not, however, occur with equal strength or at equal intervals. So far as the outcropping of the volcanic phenomena of the past is to be dated—and this not in every case with the desired accuracy—the uprising and the eruptions of volcanic masses cluster about the times of the great mountain-building foldings. They were generally closely connected, as is the case even to-day, with the mobile regions where this building of mountains was taking place through foldings, and occurred either near them or within them, or else in regions of active movements of the ground. As an expression of the life of the earth the rhythmical character of the phenomena of vulcanism is convincing. How does the intensity of the volcanic activity of the present

[10] Doctor Abbot has shown that as long as there is anything like the present amount of water vapor in the earth's atmosphere the effect of carbon dioxide just discussed will be nullified by the overwhelmingly greater similar effect of water vapor. (Note by translator.)

compare with that of by-gone times? The number of active volcanoes since 1800 has been 231. The number of submarine outbreaks is unknown. The vulcanism of to-day was exceeded certainly by that of the past only for a few periods of equal shortness. The area of 900 square kilometers forming the surface covered with lava from the Skaptar eruption of 1783 on Iceland, the recent and near-recent lava flows building up the Hawaiian Islands or the Aetna, do not take second place when compared with the many eruptions of the distant past. That the vulcanism of the present period stands in close temporal connection with the Alpidian folding period should in no way be taken as prejudicing its dying out in our comparison of the activities of the geological past.

Into whatever class of geological activity we probe, in no case are we led to the conclusion that evidence from the expressed movements indicates an on-coming senility of the earth. Everywhere rhythmical rising and falling, there is nowhere a continuous decrease of the curve of force. Although these rhythms in the life of the earth are so distinctly recognized, their cause is still to-day an unsolved riddle. Cosmical relations are recognized only in limited amounts and undetermined significance; or are the causes within the earth itself?

Joly only recently estimated the relations between radioactive transformations and geological phenomena. He sketched in bold strokes a picture showing how this secret force of radioactivity could broadly account for these rhythms, the "revolutions" of the building of mountains through folding and the great movements of the masses of the earth's crust. It does not lie within my task to-day to go into his arguments, the only purpose of which would be to emphasize the rhythmical nature of the geological events for the understanding of the geological "life" of the earth which we have been discussing.

If really in the radioactive processes is to be found the "magic" which might be the unique causation factor for these manifestations of the life of our earth, then under the circumstances may we not wholly lay aside the idea of any aging of the earth as interpreted in these pulses of the earth's crust? If the physical relations within the earth's crust, which Joly assumed in the compensating processes relative to the development of radioactive energy, do not occur with the complete balance that Joly assumes, if there would occur a storing up of energy beneath the earth's crust and within the earth's body, then a crippling of the earth's pulses would be rendered impossible. Instead, then, of becoming a crippled earth, of becoming stiff in its actions, may it not rather be going toward the catastrophe of a "Nova"?

I must stop the further spinning of such yarns as to the future of this earth, mindful of what that fine satirist, Roderich, once wrote in the album of a geologist:

Man sagt von deinem Wirken wohl am besten: Du prophezeist uns die Vergangenheit. (The best we can say of your work: You prophesy for us the past.)

The past of the earth, so far as geology unrolls it for us, and the present tell us nothing of an aging of the earth.

Die Erde lebt; sie altert nicht. (The earth lives; it is not growing old.)

GEOLOGICAL CLIMATES [1]

By W. B. Scott

HISTORICAL STATEMENT

Very early in the history of our science it became evident that the earth had passed through great climatic changes, and the effort to find an explanation of these changes which should be adequate and satisfactory has never ceased till this day. There has of late been a revival of interest in this problem, and many new works on the subject have appeared in this country, as well as in England and Germany.

One great obstacle in the way of finding convincing explanations for past climatic changes was the fact that since weather records have been kept no definite changes of climate could be detected, though it was admitted that those records covered too short a period of observation to be at all decisive. Some historians, notably Gibbon, in his famous Decline and Fall of the Roman Empire, have attempted to prove the reality of climatic changes within the historic period, especially in central Europe, but the evidence is not satisfactory. The appeal to agencies still in operation, the study of which constitutes dynamical geology, would seem, therefore, to be impracticable.

The uniform distribution of the vegetation of the "Coal Measures" over immense areas, involving very great differences of latitude, is of itself a problem that has not been satisfactorily solved even yet. One of the most eloquent of Hugh Miller's descriptive passages is his imaginative reconstruction of the climate and weather conditions which obtained in the great bogs and marshes of Carboniferous time. As coal is composed chiefly of carbon, which had been derived from the atmosphere through the agency of living plants, it was taken for granted at that time that all of it had existed in the atmosphere simultaneously in the form of carbon dioxide; but this would have had very remarkable consequences, many of which were not known in Miller's day. Miller does not seem to ascribe the climatic conditions to the atmospheric composition, since he gives no discussion of the causes of climatic change, but the juxtaposition of the supposed facts is suggestive.

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[1] Presidential address read before the Geological Society of America, Dec. 28, 1925. Reprinted by permission from the Bulletin of the Geological Society of America, vol. 37, Mar. 30, 1926.

Until Louis Agassiz propounded his glacial theory in 1840 it was assumed that the Recent epoch, or present time, was, climatically speaking, something altogether exceptional in the history of the earth, as before that, according to the universally accepted belief of the time, there had been throughout the ages an unbroken succession of mild and genial climates, without polar accumulations of ice and snow and with no well-marked distinctions of latitude. Agassiz's conception introduced an entirely new factor into the problem, and was, indeed, so novel and revolutionary in character that it was long rejected by most geologists; and even so late as 1895 Sir Henry Howarth, a trustee of the British Museum, stigmatized it as "the glacial nightmare." The theory made but slow progress toward general acceptance, until eventually the evidence became so cogent that nearly all geologists were converted to it. Nowadays it is taken as a matter of course and is taught in all the elementary textbooks. Thus it became necessary to account for a time of exceptional cold, though this was a matter of debate among those who accepted the glacial hypothesis.

Some of the most eminent geographers maintained that the glacial epoch had been due to a greatly increased snowfall, bringing about accumulations in the winter which could not be melted in the summer, rather than to any great decrease of temperature. Thus it was uncertain just what the problem consisted of and just what it was that called for explanation. Gradually, however, the proofs of lowered temperature rather than of increased precipitation seemed irresistible, and now everyone accepts that view of the problem. It is not necessary to assume any increase of snowfall to account for glacial conditions; but, on the other hand, temperature changes would of themselves necessarily have caused great alterations in the distribution of the rainfall. For example, the cold of Pleistocene times extended the rain belt so far southward as to make the now arid Great Basin a region of moist climate, supporting immense fresh-water lakes, while the rise in annual temperature which caused, or at least accompanied, the disappearance of the continental ice sheets restricted the rain belt to its present limits.

After the general acceptance of Agassiz's hypothesis, it was thus believed that, through much the greater part of its recorded history, the earth had had a mild, genial, and almost uniform climate, without definite climatic zones; that this condition had been broken by the cold of the Pleistocene, the partial recovery from which had led to the present order of things.

CLIMATES OF THE EARTH'S PAST

We now know, however, that the problem is much more complicated than would appear from this brief statement. In 1879

Blanford reported Permian glaciation from peninsular India—an announcement which was received with complete skepticism on the part of most European geologists, though followed by similar reports from South Africa, Australia, Brazil, and Germany. In 1905 I had the privilege of taking several geological excursions in South Africa, which had been arranged for the meeting of the British Association for the Advancement of Science, under the direction of Mr. A. W. Rogers, chief geologist of Cape Colony, and of Messrs. Hall and Kynaston in the Transvaal.

One object which was of especial interest and importance to all of the visitors at that time was an examination of the evidence for the great Permian ice cap, and the geological party contained such eminent students of glaciers as Professors Penck of Berlin, Sollas of Oxford, Coleman of Toronto, and Davis of Harvard. The distinguished Swedish geologist, Professor Sjögren, who was also of the party, told me that few continental geologists were prepared to accept the hypothesis of Permian glaciation. Yet the field demonstrations given us, especially at Riverton, on the Vaal River below Kimberley, were convincing to all of us, without exception. The bowlder clays and moraines and the ice pavements, with their characteristic polishing and striation, their hummocks and *roches moutonnées*, were every whit as complete evidence of glaciation as were the corresponding Pleistocene phenomena at home, and of precisely the same nature.

But even the Permian (or "Permo-Carboniferous," as the English geologists prefer to call it) glaciation was not the only ice age of long past epochs. There is evidence, as yet incomplete, of glaciation in the Carboniferous of North America. The Bokkeveld of South Africa, a marine Devonian formation, contains large, faceted, polished, and striated pebbles and cobbles of unmistakable glacial origin, but ice pavements and bowlder clays of this period have not yet been found. The Silurian moraines of Norway were probably of local origin and do not indicate any widespread climatic changes.

Very extensive bowlder beds, observed in China and Australia and originally referred to the Cambrian, are now placed in the later pre-Cambrian eras, while the tillites described by Professor Coleman in Ontario and those of British Bechuanaland in Africa are of a still more ancient date. Thus we have the remarkable fact that glaciation on a continental scale has repeatedly occurred, not less than five times and perhaps more, in the recorded history of the earth. These recurrent climatic phenomena can not be called rhythmical because, so far as we can judge, the intervals between them were not of similar length, features which render the problem of causation all the more complex and difficult.

So far as the ancient glaciations are concerned, the distribution of the ice is still a matter of uncertainty, because obviously only a relatively small part of the glacial deposits and ice pavements could have been preserved, in accessible positions, from such long-distant times. These ancient glaciations, too, add greatly to the complexity of the problem because of characteristics peculiar to themselves. For example, in South Africa, and perhaps also in Brazil, the movement of the Permian ice was from north to south, from the Equator poleward, the opposite of what we should have expected it to be. Furthermore, the enormous thickness of the bowlder beds, 1,000 feet or more, called the Dwyka conglomerate, fairly staggers the imagination when one compares it with Pleistocene moraines. The occurrence of great bowlder beds in peninsular India, so near the Equator, is a very puzzling circumstance, which some climatologists believe can be explained only by a shifting of the earth's poles.

Because of those uncertainties, it will be advantageous to confine our attempts at explaining glacial climates to the Pleistocene, because the evidence is still so very extensively and perfectly preserved, that the distribution of the Pleistocene ice sheets and mountain glaciers can be determined with a certainty which can not be attained in the more ancient periods of ice action. If we can find a satisfactory explanation of the climatic phenomena of the Pleistocene, we shall not have far to seek for an explanation of the more ancient ice periods.

There would seem to have been no glaciation on a continental scale between the Permian and the Pleistocene. Throughout the Mesozoic and most of the Tertiary periods indications of climatic zones are obscure and doubtful, and there can have been no great accumulation of ice and snow at the poles. The Jurassic sandstones of the now utterly desolate Antarctic Continent have yielded Cycad leaves much like those of contemporary Great Britain, and the Arctic fossil floras of Greenland and Alaska clearly demonstrate that, so late as the Eocene at least, these polar lands had luxuriant forests of large trees of the kinds familiar to us in temperate latitudes—a fact which indisputably proves the prevalence of much milder climates. That the Arctic regions were cooler than the area now covered by the United States is indicated by the absence of large reptiles, of palms and other subtropical forms from the far north, while they occur from Idaho and Montana southward; and the Eocene flora of the southeastern coastal plain, so beautifully reconstructed by Professor Berry, demonstrates a far warmer climate than that of to-day, though not properly to be called tropical.

In the interior of the continent, in the region of the northern Great Plains, there is a distinct climatic change between the Eocene and Oligocene, palms and large crocodiles disappearing from the area where they had been prevalent and abundant since the Middle Cretaceous. The change, though definite, was not extreme, and may well have been due rather to an increased altitude than to any general modification of climate. The Miocene flora of central Colorado was, except for the absence of palms, much like that of the northern Gulf region at present. The gradual refrigeration which marked the climatic transition from the warm Miocene to the cold Pliocene is best registered in Europe. The German lignites, or brown coals, of Miocene date, have preserved a very full representation of the plants. In the older lignites the flora is that of the Mediterranean lands, with palms and other warm temperate trees, while the upper lignites of the same region indicate principally coniferous forests. The marine Pliocene beds in the east of England have beautifully recorded the oncoming cold. In the lower strata those beds contain 5 per cent of Arctic shells, a proportion which rises to 60 per cent in the upper strata.

In the far north the Pliocene climate must have been severe, as is indicated not only by the Arctic species of shells just referred to, but also by the Pleistocene mammals, which descended to comparatively low latitudes before the advance of the ice. The familiar instances of musk oxen in Kentucky and Arkansas, caribou on Long Island Sound, seals and walruses on the coast of Georgia, mammoths and reindeer in the south of France, lemmings in Portugal, all show a complete Arctic assemblage of mammals, both terrestrial and marine. These could not have been developed overnight; they must have passed through a long period of adaptation to a climate which was steadily growing colder. The onset of glacial conditions found a fully adapted fauna of Arctic mammals, with nearly uniform circumpolar distribution, though some forms, such as the woolly rhinoceros, were confined to one or the other continent, for reasons that we can not even conjecture.

The interpretation of the Pleistocene deposits, even after their icemade character had been generally acknowledged, led to a long-drawn-out debate. Was the glacial epoch single or multiple? That the ice had been subject to many episodes of advance and retreat was admitted; the question was: Were these episodes mere fluctuations in the extent of the ice sheets, or were there actual interglacial times, when the ice altogether disappeared and the climate was greatly ameliorated? Time fails me to give any but the most superficial reference to this famous discussion. Sufficient to say that it is the all but unanimous opinion of students of this problem that there

were several truly glacial and interglacial stages when there were great climatic changes, and some, at least, of the interglacial times were actually warmer than the present. Very convincing evidence to this effect has been found on the north shore of Lake Ontario, near Toronto. There a series of stratified, water-laid clays, contained between two bowlder beds, is divisible into an upper and a lower series. The lower and older series has many fossil plants which indicate a flora such as now occurs several hundred miles to the south, in Kentucky and Tennessee. Of the upper series, the fossils resemble Labrador species and eloquently indicate the return of the cold, culminating in the ice sheet which deposited the upper bowlder beds. Professor Coleman has reported that on the shores of Hudson Bay large forest trees are found between two ground moraines, trees which are indicative of milder climatic conditions than those of Recent time in that latitude.

Similarly, the interglacial mammalian fauna which occurs at Afton, Iowa, is decidedly suggestive of a warmer climate than the present for the region involved. In this case, however, the evidence is less convincing, for the habits of extinct species of mammals can only be conjectured, and as in the famous case of the Siberian mammoth, some ludicrous mistakes have been due to inferences concerning the climatic adaptations of extinct species, reasoning from the distribution of their existing allies. Whether all the interglacial stages were characterized by a warmer climate than that of modern times, it is not yet possible to determine for lack of the necessary fossiliferous deposits.

In any satisfactory theory of the Pleistocene climates we must account for world-wide climatic change, or series of changes, so that local causes are inadequate, for in all of the continents of both Northern and Southern Hemispheres there is proof of the great extension of glaciers in that period of time. Inasmuch, however, as the Southern Hemisphere is chiefly a region of sea, with but a relatively small amount of land, climatic fluctuations in that hemisphere have been and still are much less extreme than in the Northern, where there is so large a proportion of land. This is an explanation of the fact that in the South Temperate Zone Pleistocene glaciation was much less extreme than in the corresponding northern belt. This southern glaciation, as is so well exemplified in Patagonia, was chiefly confined to a great extension of the mountain glaciers rather than to the formation of continental ice caps, such as appeared in Europe and on so vast a scale in North America.

Penck has made it very probable that all over the world the snow line was lowered approximately 4,000 feet below its present altitude—an amount which he first deduced from his studies in the Alps and

subsequently confirmed by very widespread observations in other continents. Even in the Tropics the same rule would seem to apply. Mount Kilimanjaro, the highest mountain in Africa, which stands very near the Equator (3° south latitude), still has snow fields and glaciers near the summit, while the unmistakable ice marks of polishing and striation extend more than 5,000 feet below the present limit of the glaciers—a very different thing from the snow line. To produce such climatic conditions, Penck has calculated that a lowering of the annual average temperature of about 9° F. below the existing standard would suffice. That amount, 9° F., is all that stands between us and a recurrence of glacial conditions.

In brief, therefore, what we must account for is the long continuance, throughout the Mesozoic and earlier Tertiary times, of genial, nearly uniform conditions of climate, with zones only obscurely demarcated. There was then, and probably always has been, a difference of temperature between the Equator and the poles, as is indicated by the distribution of fossil floras, but a difference far less in amount than that which now obtains. In the latter half of the Tertiary period began a slow and gradual refrigeration, which had brought severe conditions in high latitudes in the early Pliocene—conditions in which the typically Arctic fauna of mammals had been differentiated. The increasing cold finally culminated in the widespread glaciation of the Pleistocene; but this was itself highly complex, from the climatic point of view. Within a short space of time, as geological time is measured, there were many extreme fluctuations of climate, four or more glacial, alternating with interglacial stages. It would be going beyond the evidence to say that in all the interglacial stages the climate was milder than at present, but it may have been so in all, and certainly was in some. Finally, the conditions were once more ameliorated, bringing about the present order of things.

This is far from being a complete statement of the problem of geological climates, or even of the temperature factor in climates, but in this abbreviated and simplified form it will suffice for our present purposes. The solution of the problem in this form will offer quite sufficient difficulty for an evening's consideration. Only a brief mention of the cognate climatic factors—moisture, precipitation, and prevailing winds—is permissible because of the limitations of our time.

THEORIES TO EXPLAIN GLACIAL EPOCHS

Wherever it is feasible, I have always thought that there is an especial charm in presenting scientific theories historically, as this method records the progress of discovery and interpretation, the

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modifying of view necessitated by the discovery of new facts, and reveals the steps by which we have so gradually and laboriously advanced from the known into the unknown.

In this manner we should learn that more than half a century ago hypothetical explanations of climatic change were put forward which, essentially and in principle, were almost exhaustive of the known possibilities. Sir Charles Lyell sought the explanation in widespread and radical changes in the distribution of land and sea. Taking the present continents, he showed that, without any alteration of size, shape, or altitude, great climatic differences could be brought about by grouping these land masses, first, as closely as possible around the Equator, and subsequently around the poles. The Vienna geologists, supported by the eminent astronomer, Father Secchi, maintained that the earth's axis, and with it the poles, had been shifted, bringing certain regions which were formerly Arctic into the Temperate Zone, and thus changing their climate very completely.

Dr. James Croll, of the Scottish Geological Survey, published his Climate and Time in 1875, a book which speedily became famous. Croll called attention to the fact that the size and shape of the earth's orbit were not constant, but subject to change, which resulted in periods of maximum and minimum eccentricity. He contended that the hemisphere which had its winter in aphelion during a time of maximum eccentricity would pass through a period of glaciation. On this hypothesis glacial periods would recur alternatingly between the Northern and Southern Hemispheres and rhythmically every 12,500 years.

I have not been able to learn who it was that first suggested the internal heat of the earth as the cause of the former mild and uniform climates, and the gradual loss of the earth's heat by radiation as having brought about the refrigeration of climate which has led to the present order of things. This conception is nearly as old as geology or the nebular hypothesis of Laplace. In modified form it has lately been revived by Doctor Knowlton.

Finally, I may mention Lord Kelvin's [2] suggestion that the cause of climatic changes on the earth should be sought in fluctuations of the sun's activity, a suggestion which seemed to be made obvious by the connection between the weather and the maxima and minima of the sun-spot periods. Among geologists it is, perhaps, Professor Penck who has most strongly championed this view, for it is he who has most clearly brought out the universal nature of the climatic changes in the Pleistocene.

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[2] The hypothesis of solar change as causing climatic changes on the earth was adopted by Penck. Prof. H. F. Reid kindly pointed out to me the fact that the suggestion was originally due to Lord Kelvin.

Though the historical method of approach is the more interesting and, perhaps, the more instructive, it is in the interests of brevity and lucidity to deal with the various hypotheses which have been propounded to explain the climatic changes which have occurred in the recorded history of the earth in a more systematic manner. The subjoined table presents a classified arrangement of the principal hypotheses which have been offered in explanation of the problem of climate. Obviously, it will not be practicable to devote more than a very brief time to the discussion of the various hypotheses.

I. Terrestrial causes.
- A. The earth as a whole.
  - (1) Changes in the eccentricity of the orbit.
  - (2) Shifting of the earth's axis.
  - (3) Shifting of the earth's exterior on the interior.
  - (4) The internal heat of the earth.
- B. Atmospheric factors.
  - (1) Variation in the proportion of carbon dioxide.
  - (2) In the amount of suspended volcanic dust.
- C. Oceanic factors.
  - Variations in salinity.
- D. Topographical factors.
  - Changes in the area, altitude, and disposition of the land masses.

II. Cosmical causes.
- A. Passage through cold regions in space.
- B. Variations of the sun's activity.

As the table indicates, the methods of explanation fall into two principal categories: (1) The terrestrial, in which the source of change arose on the earth itself; and (2) the cosmical, in which the cause lies outside of the earth or even outside of the solar system. Of the terrestrial agencies of change we may make two groups: (*a*) Those which affect the earth as a whole, and (*b*) those which are more or less local and partial in their operation.

A. (1) Croll's hypothesis was published when I was an undergraduate and just beginning the study of geology, and I can well remember the enthusiasm with which it was received in this country. "At last," we said, "the climatic mystery, which has been troubling us for so long, has found a solution." But the enthusiasm was short-lived, for its requirement of an ice age at intervals for each hemisphere of 25,000 years was found to be incompatible with the ascertained facts of geological history. Probably Doctor Croll himself would have been aghast at the number of glacial periods which the earth must have passed through, according to his supposition. The ten or at most twenty million years which in 1875 were allowed for the age of the sun have been almost indefinitely extended by the later physical discoveries. Had ice ages occurred with the rhythmical

regularity which Croll postulated, the Northern and Southern Hemispheres must each have had some 40,000 of them, which does not seem likely.

A. (2) Shifting of the earth's axis and the concomitant changes in the position of the poles are by most astronomers declared to be impossible. Into this astronomical problem we need not enter, for no position of the poles which has yet been suggested would get rid of the necessity of admitting climatic change. This hypothesis and the following one are not, strictly speaking, attempts to explain climatic changes, but to account for the distribution of fossil floras and faunas without assuming important changes in the earth's atmospheric temperatures.

A. (3) A shifting of the earth's outer shell on the interior is a hypothesis much like the preceding, but differs in the suggested mechanism of change. Thus Wegener suggests that the vast Permian glaciation in the Southern Hemisphere was due to the junction of the southern continents around a pole in the Indian Ocean and that they have since drifted apart. But this suggestion, even if true, would not account for the facts; as Lake has pointed out, Permian ice sheets covered northern Baluchistan, which, according to the hypothesis, would then have been in the Tropics. Concerning the possibility of the shift itself Jeffreys remarks:

A displacement of this type would produce important climatic changes, but so far no agency capable of producing it has been suggested.

A. (4) It was long supposed that the ancient geniality and uniformity which, for such vast stretches of time, characterized the earth's climate were due to the internal heat of the globe, and the present severe climates of high latitudes have been brought about by the reduction of the internal heat by radiation. Aside from the question raised by the phenomena of radioactivity, whether the earth has actually lost heat (Joly even suggests that it may be gaining, rather than losing), this hypothesis postulates a continual change in one direction and fails to account for fluctuations of climatic conditions. Since the formation of a solid crust (assuming that the globe was once fluid) the very low conductivity of the rocks must have prevented the internal heat's having much effect at the surface.

The surface temperature of the earth must have been almost wholly maintained by solar radiation practically ever since it became solid at the surface, and certainly throughout geological time. Conduction from the interior is in comparison quite unimportant. (Jeffreys.)

B. (1) The foregoing hypotheses all deal with the solid earth as a planetary unit, using the term "solid" without prejudice to the conception of possible fluid portions of the interior. We may next consider the explanations which find the causes of climatic change in

modifications of the atmosphere. It is universally understood that the atmosphere has a blanketing effect, permitting the direct rays of the sun to pass through it freely, but opaque to the dark heat reflected from the ground. In this way the air acts like the glass in a cold frame, which Tyndall poetically called "a trap to catch a sunbeam." This blanketing effect is least in thin, dry, and pure air and is greatly increased by the presence of vapor of water and carbon dioxide in the atmosphere. It has seemed a natural inference that a large augmentation of the amount of carbon dioxide present in the air would so raise the blanketing effect that genial climatic conditions would be produced, even in the polar regions. There is, however, a fatal objection to this inference revealed by experiment, namely, that the amount of carbon dioxide already normally present in the atmosphere exerts nearly the maximum blanketing effect, and a large increase in the amount of gas would not produce a corresponding rise of temperature.

B. (2) A screen of volcanic dust remaining long suspended in the upper atmosphere, as did the fine dust after the great eruption of Krakatoa in 1883, might so cut off the sun's heat as to cause a refrigeration of the earth's surface temperature, and such a screen has actually been appealed to as a cause of glacial climates; but the supposed cause seems neither actual nor adequate. There is nothing in known geological history which would justify us in supposing that such masses of volcanic material, diffused over the whole earth, were ever maintained for tens or hundreds of thousand years. The geological periods in which vulcanism was most active, such as the Ordovician and the Devonian, were not those of widespread glaciation. Indeed, the opposite conception is held by those who find the explanation of higher air temperatures in the greatly increased content of carbon dioxide; they maintain that the most actively volcanic periods were the warmer ones, the carbon dioxide being supplied by the volcanoes.

C. Ocean currents are familiar means of modifying climates, the warm and cold currents having a marked effect on the air with which they come into contact. It has been maintained that variations in the density of sea water, due to changes of salinity, would greatly modify the system of oceanic circulation. To this it may be objected that the great ocean currents are due to prevailing winds, and so long as the system of winds remained unchanged variations in the density of the water could have little effect on the currents.

D. Changes in the size, distribution, and altitude of the land masses were, as we have already seen, first invoked by Lyell to explain the earth's vicissitudes of climate, and of late there has been a strong revival of interest in causes of this nature, and three quite

recent books appeal to them as all sufficient for the purpose. Mr. C. E. P. Brooks has of late years (1922) published a very valuable and suggestive little book, The Evolution of Climate, which is devoted to this thesis. Professor Berry, from a study of the fossil floras of North America, reaches the same conclusion, as does substantially Professor Ramsey, of Helsingfors, who published his observations and deductions in volume 64 of the Geological Magazine. To say the least, it is a remarkable coincidence that so many and so widely separated investigators should have reached the same conclusion from somewhat different kinds of evidence. In his lately published book, The Earth, its Origin, History, and Physical Constitution (1924), Dr. Harold Jeffreys, of Cambridge, devotes a considerable part of the appendix on "Theories of climatic variation" to an examination and criticism of the work of Brooks. It will serve our purpose excellently to quote a few extracts from Jeffreys' review:

> In this way Brooks is able to show that more oceanic conditions, which actually existed, are quantitatively able to account for the mild climate of the Eocene period. A general elevation of the land proceeded throughout the Tertiary era, and when the Scandanavian highlands and the Rocky Mountains reached the snow line an ice sheet commenced to form. * * * The actual events during the glacial period and afterwards agree closely with Brooks's inferences. In particular, some sand dunes in north Germany, formed at this time, have their tips pointing to the west instead of the east, showing that the prevailing wind there at the time was from the east. This is exactly what would be expected from the presence of the Scandanavian ice sheet, which would produce * * * east winds over Germany. In many other parts of the world striking agreements are found. * * * Brooks's theory is, therefore, a very substantial contribution to our understanding of climatic change; but it does not furnish a complete explanation. * * * It appears as if the later stages, at least, of the elevation of the mountains took place under conditions when the snowfall was inappreciable, and that the ice sheet did not begin to form until some further change of climate, not attributable to the mountains, had supervened. The Cambrian, Ordovician, and Silurian folds, again, must have raised mountains quite comparable to those of the Tertiary, but do not appear to have been followed by glaciation on anything like the same scale, again suggesting that mountain formation, though it may be a necessary preliminary to glaciation, is not a sufficient condition for it.[3]

An elaboration of this same conception sees in the many climatic fluctuations of the Pleistocene an isostatic response of the earth's crust to the load imposed on it by the immense accumulations of ice. The ice sheets were established, it is supposed, when the continents had risen to a high level, and under the enormous load of ice they again sank to an altitude at which the ice melted and snowfall was no longer sufficient to maintain the ice caps. Freed from its load, the land again rose to a height at which the ice was again formed, only to sink once more under the renewed load.

[3] Jeffreys: Op. cit. p. 265.

Many observations have been made which strongly suggest that the relation between loading of the land with ice and subsequent depression is more than coincidence. But if that were all, why did the process cease? Why was the last melting of the ice not followed by a renewed elevation of the land? It may be said that not time enough has elapsed since the last disappearance of the ice, and that we are slowly but surely advancing to a new glacial epoch. Perhaps so, but there is no sufficient evidence of a universal rise of the land in high latitudes, such as would be called for on this hypothesis. Furthermore, if diastrophic movements were the sole cause of the glacial and interglacial alternation, we should have no explanation of the fact that in some, at least, of the interglacial stages the climate was warmer than at the present time. Some additional factor is called for.

I can not but agree with Jeffreys in his conclusion that, while diastrophic movements of the earth's crust are a very real cause of climatic change, they are insufficient to account for the accepted history of the vicissitudes of climate through which the earth has passed. The lowered temperature of the Pleistocene was a world-wide phenomenon and is registered in all the great land masses of both Northern and Southern Hemispheres. Even in the Tropics the ice limit was several thousand feet below that of the present day. We have no satisfactory proof of a correspondingly universal upwarping of the lands, and therefore the diastrophic hypothesis, as it may be called, is inadequate as the sole explanation of the facts.

It should be added that a great deal remains to be learned concerning the Pleistocene glaciation of the Southern Hemisphere, for little intensive study has as yet been devoted to the problems involved. It is not definitely known, for example, whether glacial and interglacial alternations characterized the continents of the Southern as they did those of the Northern Hemisphere, nor how many glacial stages there were, or if, indeed, there was more than one. Obviously, a complete theory of the Pleistocene climates can not be formulated until much more has been learned regarding the southern continents in that epoch.

II. So far we have dealt entirely with supposed agencies of climatic change which have affected the earth only, either as a whole or in part. In the second principal category of hypotheses the causes of climatic change are sought for in agencies entirely outside of the earth, and therefore cosmical rather than terrestrial. Croll's famous theory might almost as well be put in the cosmical as in the terrestrial class, though it deals solely with the earth.

A. It has been suggested that the solar system, in its known swift passage through space, traverses regions of different temperature,

which would produce a corresponding modification of the earth's climates. This purely fanciful conception need not detain us, for space can have no temperature, which is a property of matter. That the earth could have received an appreciable amount of heat from some luminary other than the sun would involve so near an approach to another star as to upset the equilibrium of the solar system.

B. By a process of elimination we seem to be shut up to the conclusion that we must look for the primary causes of changes in the earth's climates in the sun itself, as originally suggested by Lord Kelvin. As we have just seen, the various terrestrial agencies which have been called on to explain these changes are inadequate of themselves, while changes in the sun would have universal effects. The connection between the sun-spot cycles and terrestrial weather has long been recognized, and the Smithsonian observatory, under the direction of Doctor Abbot, has shown that variations in solar radiation do actually occur, and to a surprising amount, from day to day, as well as through longer periods. The observing stations have been operated in regions of different climates and altitudes, so as to do away with the confusing effects of the earth's atmosphere. The work is still in progress, and Doctor Abbot has lately been in Africa searching for a satisfactory site on which to place another control station, and we may hope soon to have a body of established facts concerning solar activity which will be most useful in the solution of our problem. The manner in which solar changes operate on the earth is a very complicated one, and if these changes are of no very great amount they would produce different effects in the various climatic zones. This has been well brought out by Mr. Clayton in a paper read last April before the National Academy of Sciences.

As Jeffreys has pointed out, any hypothesis of this type is very difficult either to prove or to disprove; but we do know that the earth's temperature depends on the sun, and that the sun's activity is variable—not a long, slow decline. Hence arises the probability that solar changes are the principal cause of the earth's variations of climate. This conclusion does not preclude the acceptance of the terrestrial agencies as modifying the effects of solar change. Assuming the effectiveness of the latter, the Pleistocene history of the Southern Hemisphere well illustrates such modifying effect. The vast area of the seas and the relatively small land surfaces produce an oceanic climate in which extremes of heat and cold are rare. All down the west coast of southern Chile and Tierra del Fuego, almost to Cape Horn, we find an evergreen rain forest of deciduous trees, most of which belong to a single species of the southern beech (*Nothofagus*). In this region there is little difference between winter and summer;

the weather is always cold, though never extremely so. In this instance the modifying effects of solar changes are produced by the distribution of the marine and continental areas. In the Northern Hemisphere, there is much reason to believe, diastrophic movements, both the orogenic folding and the epeirogenic warping of broad areas, have had an important bearing on the effects of solar changes, now opposing and reducing those effects, now assisting and increasing them.

VARIATIONS IN RAINFALL AND THEIR CAUSES

The second great factor in the determining of climates is moisture and its resulting precipitation in the form of rain or snow. Even more than temperature, precipitation is affected by topography and prevailing winds. High mountain ranges, which cut off moisture-laden winds, may throw a "rain shadow" far across the continent, as do the ranges of the Pacific coast region. The remarkable monsoons of the Indian Ocean, a reversible system of winds, bring the rains to India when blowing from the southwest. Many similar instances of the effects of topography and prevalent winds might be mentioned, if it were worth while to do so; but these are well understood and it is not necessary to recapitulate them.

Evidences of arid climates in ancient geological times where now are regions of pluvial conditions, are abundant, and such evidences are for the most part independent of fossils and are contained in the rocks themselves. Beds of gypsum and rock salt are indicative of aridity, for they are accumulated in salt lakes, which can not be maintained in regions of normal rainfall; and the distribution of such deposits in time and space, their geological and geographic arrangement, frequently enable us to demarcate the regions of special aridity. No doubt there were many others of which we do not know, the proofs of which have been swept away by denudation. The changes from pluvial to arid conditions, and vice versa, would seem to have been local in some instances, of immense geographical extent in others.

The Ordovician of Siberia and the lower Carboniferous of eastern North America were, so far as we can judge, instances of locally restricted changes to more or less arid conditions, while nearly the whole of the Permian and Triassic periods show a belt all around the Northern Hemisphere of extreme aridity. Under the north German plain lies a vast body of rock salt of unknown thickness, for none of the very deep bore holes, which have been put down, reach the bottom of the salt. Making a reasonable allowance for the thickness of the salt body, it has been estimated that it represents the evaporation of a body of sea water three times as great in cubic content as

the Mediterranean Sea. The whole trans-Mississippian region of North America was a desert in Permian-Triassic times, though perhaps not so extremely arid as central Europe; and even the eastern part of the continent, north of Virginia, was subarid; at least most students of the Newark formation are led to that opinion by the character of the sediments.

If, now, we plot on a Mercator's chart the known arid regions of the Permian and Triassic periods, we are immediately reminded of the desert zones which in both hemispheres encircle the earth at the present time. These zones of desert are the trade-wind belts, where the equatorial outflow of heated and expanded air descends once more to the earth's surface. Such descending currents, being adiabatically warmed through condensation, are always dry, and hence the zone of desert where they impinge on the land. In both Northern and Southern hemispheres the Temperate Zones are areas in which the prevailing winds are westerlies, blowing some 80 per cent of the time from some westerly quarter. Equatorward from the westerlies in both hemispheres, lie the "horse latitudes," belts of light, variable winds, and beyond these again are the trade-wind belts. Between the northeast and the southeast trades is the equatorial belt of calms. The whole tropical wind system, with its five zones, swings north and south with the sun in its apparent path between the solstices, so that certain regions have the trade winds in summer but not in winter. Such areas are southern California and the southern parts of the great Mediterranean peninsulas of Europe—the Iberian, the Italian, and the Balkan—and these all have nearly rainless summers, the precipitation of the year being concentrated in the winter.

If we may assume that during most of the Permian and the whole of the Triassic periods there was such an increase of solar activity as to raise the surface atmospheric temperature some 8° or 10° F. above the present annual averages, this would have the effect of displacing or extending the trade-wind belt some hundreds of miles north of its present position (note well, confining our attention to the Northern Hemisphere), and with it the desert zone of the northern continents. That such would be the actual effect of a moderate rise of atmospheric temperature is made very probable by the converse effect of lowered temperature in the Pleistocene, to which reference has already been made. During the times of principal ice extension precipitation was so increased in what is now the arid and semiarid West that immense fresh-water lakes were established in the Great Basin, and almost every valley in the Colorado Rockies and in the Sierra Nevada down to middle California was occupied by a great stream of ice.

It may not seem legitimate to assume that the existing wind system extended so far back into the distant past; but as a matter of fact this system, aside from local currents, is in Davis's phrase "planetary," and is determined by the earth's relations as a planet. So long as the earth rotates on its axis and revolves about the sun; so long as its axis remains oblique to the plane of its orbit, producing differences of temperature in different regions, so long must the general system of winds remain what it is now and what we have every reason to believe it has always been from the beginning of land and sea. Raising and lowering the atmospheric temperature will undoubtedly shift the position of the wind belts, but will not affect them otherwise.

We have direct proof that in the Pleistocene, at least, the system of winds was substantially the same as now. Everyone is familiar with the fact that the western side of Europe has a much milder climate than the Atlantic coast of North America, with no such extremes of temperature. Great Britain and Labrador, Norway and Greenland, New York and Naples have much the same latitude. The difference in climate, which amounts to 10° of latitude, is due to the westerly winds, which reach Europe from the sea, eastern North America from the land. The same climatic difference, and for the same reason, obtains between the Atlantic and Pacific coasts of North America and between the American and Asiatic shores of the Pacific. During the maximum glaciation in the Pleistocene the extension of the northern ice caps was to latitude 50° in Europe and 40° in eastern North America, just such a difference as we find to-day.

The studies of Professor Huntington have satisfied most geographers of the reality of the desiccation, which has been in progress for the last 2,000 years, from central and western Asia to California. The desiccation has not been uniformly progressive, but subject to wide fluctuations, though the algebraic sum of the fluctuations is greatly increased dryness. Whether this increasing aridity can be correlated with rising temperature is not yet known, but it must be said that we know no cause of desiccation except greater heat.

I should, perhaps, apologize to the members of the society for selecting as the topic of this address so hackneyed a problem as that of geological climates, in which it is hardly possible to suggest anything that has not been suggested many times before. It is, indeed, a threshing over of old straw. Yet there has been so emphatic a revival of interest in the problem of late years that I thought it might serve a useful purpose to offer a brief consideration, in classified form, of the many factors of climatic change which have been brought forward in many lands and by many writers.

GEOLOGIC ROMANCE OF THE FINGER LAKES [1]

By Prof. Herman L. Fairchild

University of Rochester

[With 6 plates]

Superlatives have been exhausted in praising the parallel lakes of New York. They deserve the praise. But the beauty of the lakes and the charm of their setting are not more deserving than is the dramatic story of their making.

In the lakes themselves there is no mystery. The water bodies merely fill the land depressions to overflowing. The romantic interest lies in the origin and history of the basins which hold the lakes.

A misleading theory in former years, which yet appears in print, claimed that the basins were scooped out by a plowing action of the ice sheet of the glacial period. This explanation, which was even applied to the great Ontario Basin, was a popular and easy way of avoiding a complex problem in New York physiography. The fact that the bottom of Lake Cayuga is 54 feet below ocean level, that of Seneca 174 feet, and that of Ontario nearly 500 feet, was the singular and puzzling feature. But the Quebec Glacier, which overspread New York and New England and which admittedly had some abrading effect, was not guilty of the valley deepening, although it had some part in producing the basins.

The purpose of this writing is to describe the formation of the Finger Lakes basins, a romance in geology. The physical conditions and the length of time are so far beyond human experience that to appreciate the facts of the story requires of the reader some mental exercise, with constructive imagination. Many people do not like facts, if new, but prefer a world of unreality. If the reader happens to be of the latter class, he would better break away right here. Yet the story, like many truths of nature, surpasses any fiction of man's invention.

We are so familiar with many lakes, large and small, that they seem to be normal and permanent features. On the contrary, they

[1] Reprinted by permission from the Scientific Monthly, August, 1926, Vol. XXIII.

are unusual, exceptional, and transitory. Excepting the peculiar ones in Florida and on the Mississippi delta there are few lakes to-day in America, outside of glaciated territory. The oxbows in the flood plains of rivers are not counted.

Most lakes may be defined as expansions of streams. But the basins or reservoirs are not made by the streams in normal flow. Some external interference or damming effect is necessary. Streams can not permanently dam themselves. Ice jams, log jams, and landslides make temporary reservoirs. The singular and beautiful lakelets near Syracuse, one in a State park, occupy cataract plunge-basins and are of very exceptional and interesting character. With their bounding cliffs they are fossil Niagaras. To-day Niagara Falls is drilling a similar bowl. The Syracuse Basins were carved by rivers which in function were true predecessors of Niagara. They were held up in forced flow by the front of the waning glacier. Perhaps they are the best example of streams making basins. But these lakelets did not exist while the rivers were flowing.

In regions of land movement, as mountain districts, basins are sometimes produced by the bending and the breaking of the earth's crust. The Jordan Valley and Dead Sea are examples of the latter. The basin of Lake Superior is thought to be due in part to crustal warping. But the basins of the Finger Lakes are in practically horizontal strata, lifted out of the sea and without serious deformation.

As reckoned in geologic time, lakes are short-lived. They disappear either by the downcutting of their outlets or by the filling of their basins. Sand and silt are swept in by streams and by winds in arid regions, and vegetable growth assists the filling process. Shallow lakes which recently existed in some of the New York valleys have already become plains or swamps. The extensive plains at the heads of the Finger Lakes, Seneca and Cayuga, for example, show the rapid filling by the detritus swept in by the inlet streams.

The scores of thousands of lakes and lakelets in our Northern States and Canada came into very recent existence with the melting away of the Canadian ice sheets. Previous to the glacial invasions there were few, if any, lakes in eastern America. This implies that the Finger Lakes are not old. Indeed, they are very young, speaking in geologic lingo. Their life is reckoned only in tens, or at most, in scores of thousands of years. But the valleys in which they lie have been in the making for uncounted millions of years. The Finger Lakes are about the latest geologic features in the State. The cataracts and canyons are younger. Lake Ontario is the youngest great physiographic feature in America.

The origin of the parallel valleys must first be learned, and then how they came to be dammed. This series of parallel valleys is

probably the most notable in the world. That may sound like American bravado, but the challenge stands. Starting with the upper Tonawanda (Attica) Valley on the west, and passing eastward, the other pronounced valleys are: Oatka (Warsaw); Genesee; Conesus; *Hemlock; Canadice; Honeoye;* Mud Creek (Bristol); *Canandaigua;* Flint Creek (Gorham-Orleans); *Keuka; Seneca; Cayuga; Owasco; Skaneateles; Otisco; Onondaga;* Butternut (Jamesville); Limestone (Fayetteville); Chittenango; Cowaselon; *Oneida.* The valleys which now hold lakes are marked by italics. (See fig. 1.)

All these valleys drain northward into Lake Ontario. The series might fairly include a number west of the Tonawanda, that swing around into Lake Erie, and others on the east which lead into the Mohawk River. Some of the valleys, as the Oatka, Genesee, and Flint, once held lakes that are now represented by plains.

The making of these north-leading valleys is a part of the story which makes demand on the scientific imagination. The history covers the many millions of years since central and western New York were permanently lifted out of the sea. The clear record of the long marine submergence is seen in the rock strata, several thousand feet in thickness, filled with remains of the varied life of the ancient seas. Remnants of the nearly horizontal strata constitute the broad, arching ridges between the valleys, with elevations up to over 2,000 feet above sea level. The valleys are the positive effect, having been carved by atmospheric and stream erosion out of the uplifted land.

When the area of the western part of New York had been permanently raised out of the sea, it was a vast plain, declining southward. The Ontario and Mohawk Valleys did not exist. All the stream drainage of the area was southward, from Canada across New York into Pennsylvania. A wide belt of comparatively weak rocks lay east and west where the Ontario and Mohawk Valleys are now. In that belt the east and west tributaries of the primitive south-flowing rivers had an advantage, on account of the weaker resistance of the underlying rocks. They cut down faster and captured, or "beheaded," the rivers from Canada and developed the east-and-west depression that initiated the Ontario and Mohawk Valleys.

Eventually a great trunk river, which we call Ontarian, occupied the depression that is now the Ontario Valley, probably flowing westward to the Mississippi. Of course, this great valley had two walls or drainage slopes. On the south wall, sloping northward, the streams flowed northward into the Ontarian River. During the long geologic time, probably part of the Mesozoic era, or age of reptiles, and certainly during the succeeding long Tertiary period, or age of mammals, the Ontario Valley was deepening and widening.

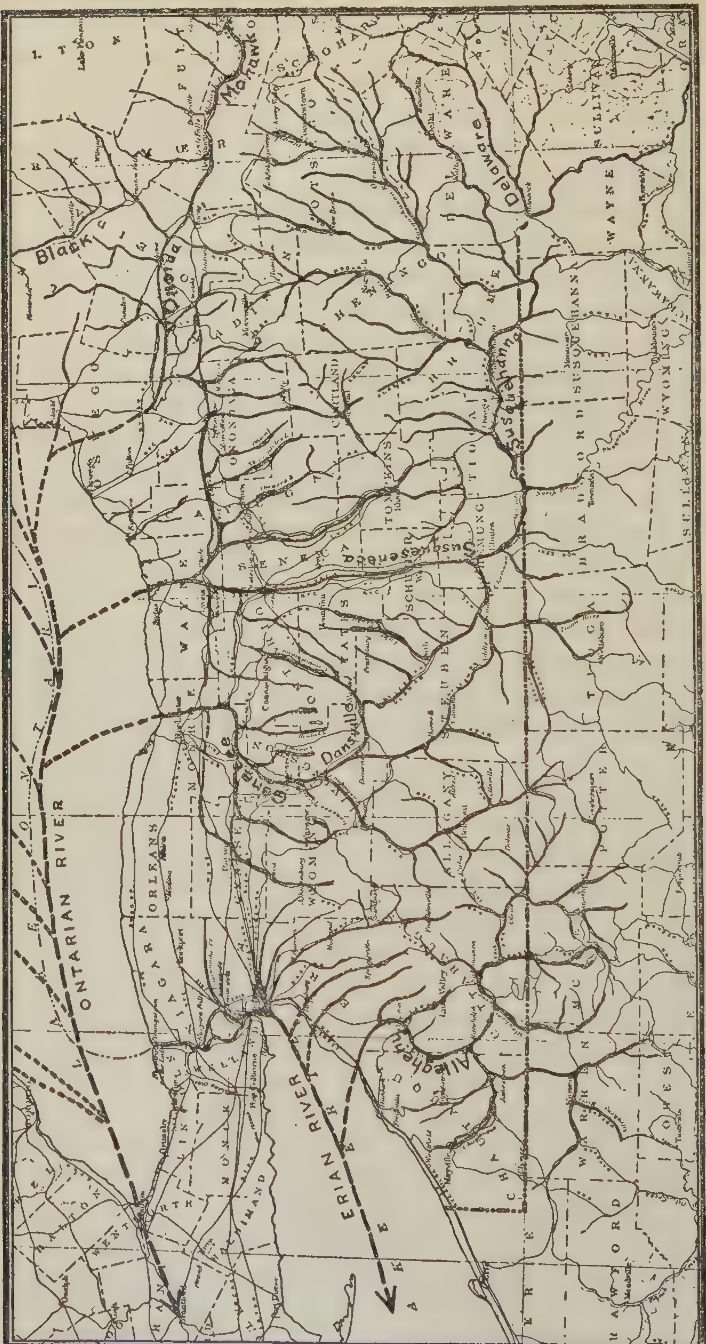


FIG. 1.—LATE TERTIARY, OR PREGLACIAL, DRAINAGE OF CENTRAL AND WESTERN NEW YORK

Glacial drift has so obscured the ancient river courses, especially over a wide belt near Lake Ontario, that the mapping is partially hypothetic

Its tributaries from the south were doing the same, and by headward erosion were eating back, southward, into the highland of the southern belt. Eventually these north-flowing rivers deeply intrenched the highland, even into Pennsylvania. Thus all western New York and a belt of northern Pennsylvania was drained north into either the Ontarian or the Erian Rivers. (See the map, fig. 1.)

It must be recognized that this northward New York drainage was the reverse in direction of the original, or primitive, flow on the old coastal plain. Of course the Canadian streams retained their southward flow, as seen to-day, until they reached the Ontarian River. The upper Susquehanna and its upper tributaries are probably persistent examples of the primitive southward flow, but they have been beheaded by the Mohawk, flowing eastward.

The parallel valleys of New York were carved in preglacial time by north-flowing rivers; with the possible exception of Canandaigua and Keuka Valleys, which appear to have retained, through some distance, the primitive southward flow. But even their streams became tributary to the northward flow. (Fig. 1.) If we ever have a geographic survey of the buried rock topography, it will doubtless show that the bottoms of the Irondequoit, Seneca, and Cayuga Valleys are graded to the bottom of Lake Ontario. This will fully account for the depths of the unfilled portions of these valleys.

One surprising element in the reversed drainage (shown in the map) was the capture of the old Susquehanna River. First it was diverted to westward flow, as retained to-day, through Binghamton, Owego, and Waverly. But it is believed that it was turned northward at Elmira and did the chief work of deepening the Seneca Valley. We might call this great river the Senecahanna, or the Susqueseneca. Most of the northward drainage in New York appears to have been concentrated in the Genesee and the Susqueseneca.

We now have found the origin of the parallel valleys. Three questions now occur. Why the valleys are cut below sea level; how they were dammed, to hold lakes; and the cause of the digital arrangement, like fingers on the palm of the hand.

It is difficult for people in quiet portions of the continent to realize that the land is not fixed and eternal. People in earthquake-ridden areas know better. Even continental areas move slowly up and down. During the long eons while the valleys were making, the land of eastern America was probably seesawing, up and down, as it had been doing in earlier time. Just previous to the glacial period it probably stood much higher than it is to-day, possibly two or three thousand feet. Certainly the bottom of the Ontario Valley was high enough to allow efficient flow to the sea of the Ontarian

River. During the long earlier history of the north-flowing rivers, with lower and more steady position of the land, the valleys were greatly widened. Later, by the Tertiary uplift, the rivers were enlivened or rejuvenated, and they sawed down more rapidly, producing the narrower, and steeper-walled, bottom sections of the valleys.

Rivers are the valley makers. Mountain or Alpine glaciers modify the valleys which they occupy. They are chiefly agents of transportation. Their minor work of erosion tends to widen rather than deepen their channels. They change stream, or V-shaped valleys, into U-shaped. But the ice work in New York was not that of stream glaciers but that of a widespread or continental ice sheet. It had little power of deepening valleys, but was effective rather in filling and damming the valleys. Lobations of the ice margin pushed into the old valleys, during both the oncoming and the recession of the glacier. But the lobes, pushing up the valleys, with imprisoned lakes facing them, were heavily loaded with rock-rubbish (glacial drift), and had little power of erosion. Moreover, the bottom ice in the deep valleys is believed to have been comparatively stagnant, serving as the bridge for the flow of the plastic upper ice. When the ice sheet was thick it moved southwestward, or diagonally across the central valleys. And, as noted above, the later lobations were too heavily loaded with bottom drift to do effective cutting. They piled their drift burden mostly in the hummocky deposits that now make the divides or water parting south of the lakes. (See fig. 2.)

In general the ice sheet had only a smoothing or sandpapering effect on the land surfaces. It rubbed down the projections and filled the depressions, thus producing the remarkably uniform curving surfaces which give the slopes of the Finger Lakes valleys their graceful outlines.

During the later stand of the Quebec ice sheet it completely filled the northern ends of the valleys with its drift deposit, forming the wide plains north of the lakes. This drift filling makes the dams that hold the lakes.

In addition to this northern blocking of the valleys another agency has helped to make the basins. This is the tilting uplift of the land. The weight of the Quebec ice cap, many thousand feet thick, depressed the land. When the ice was removed the land rose, slantingly in New York. The amount of slant, or uptilting, has raised the north ends of Cayuga and Seneca Lakes about 80 feet more than the south ends. As the outlets are at the north ends, it is evident that the land movement is partly responsible for the lake basins.

However, the "basin" character has been overemphasized. A true vertical profile of the basins shows that they are comparatively

shallow. If the depth of Lake Seneca (618 feet) be represented on a diagram by 1 inch, then the length of the lake (36 miles) would be 26 feet. On the same scale the length of Cayuga would be 40 feet. And if the depth of Ontario be diagrammed as 1 foot, the

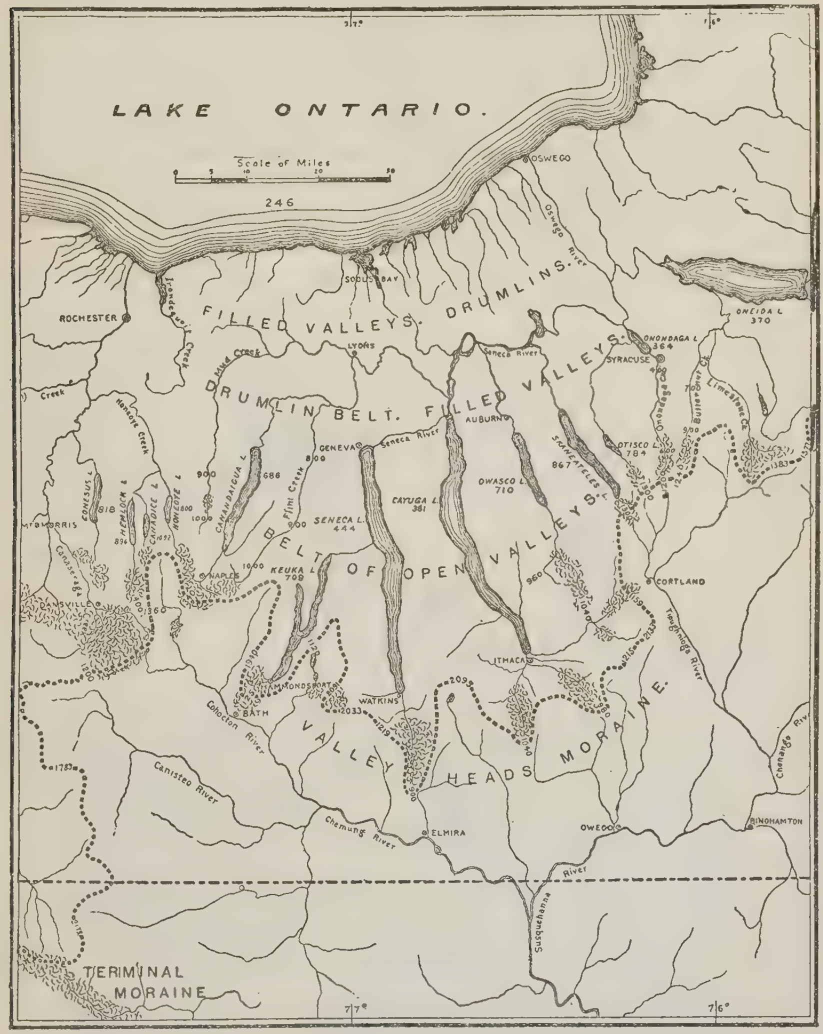


FIG. 2.—Finger lakes and physiographic belts in central New York

length of the lake would be nearly one-fourth of a mile. Evidently, no appeal is necessary to a fanciful deepening by "glacial erosion."

The singular direction of the central valleys, converging northward, is an effect of the stream flow being directed by the general slope of the broader land surfaces, and the latter being determined by the character of the rocks in which the valleys were carved.

As stated above, the east and west Ontario-Mohawk depression was initiated on the outcropping belt of weak strata, and it became the master valley because of the great thickness of these nonresistant strata. In New York these weak strata are thickest on the meridian of Seneca and Cayuga Lakes, where in the vertical series of 5,150 feet of strata, between the Trenton limestone below and the Portage sandstone above, 4,500 feet are weak shales, 350 feet soluble limestone and only 250 feet sandstone. Consequently the south wall of the great Ontario Valley in the district of the Cayuga and Seneca tributaries receded rapidly producing the decided concavity as shown by the south shore of the present lake. Naturally the northward stream flow was directed by the prevailing land slopes and converged toward the district of more rapid erosion.

The complex history of the Finger Lakes may be summarized as follows:

(1) The original drainage on the uplifted sea bottom, or coastal plain, was southward across New York from Canada. Only a few

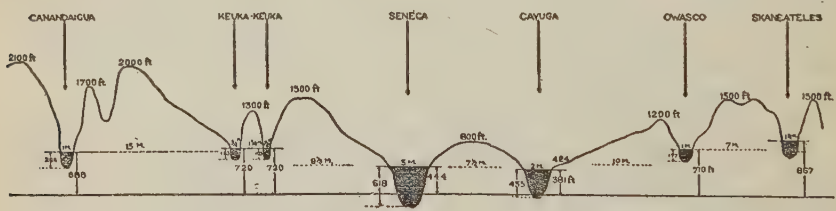


FIG. 3.—Profile of lake region showing depth and greatest width of lakes. Base line is sea level

remnants of that primitive flow now exist in western New York, with the upper Susquehanna and its tributaries in the eastern district.

(2) Evolution of the great east-and-west Ontario Valley, in a wide belt of weak rocks, shales, and limestone, by the Ontarian River, beheaded the Canadian rivers.

(3) Northward tributaries of the Ontarian River, on the south side of the expanding valley, ate back (southward), by headwaters erosion, into the Allegany Plateau, even to Pennsylvania. In this way was developed the remarkable series of parallel valleys; the reverse, in direction, of the original drainage. (Fig. 1.)

(4) High elevation of eastern America, in later Tertiary time, enlivened the rivers by increasing their fall to the sea, and hence their velocity. This caused rapid down-cutting of the valleys (fig. 3), so producing the steeper lower walls of the central lakes, and the convexity of the slopes.

(5) The high elevation of eastern America, possibly accompanied by a slight lowering of world climate, produced vast and deep ice sheets. The latest one, the Quebec Glacier, overspread New York,

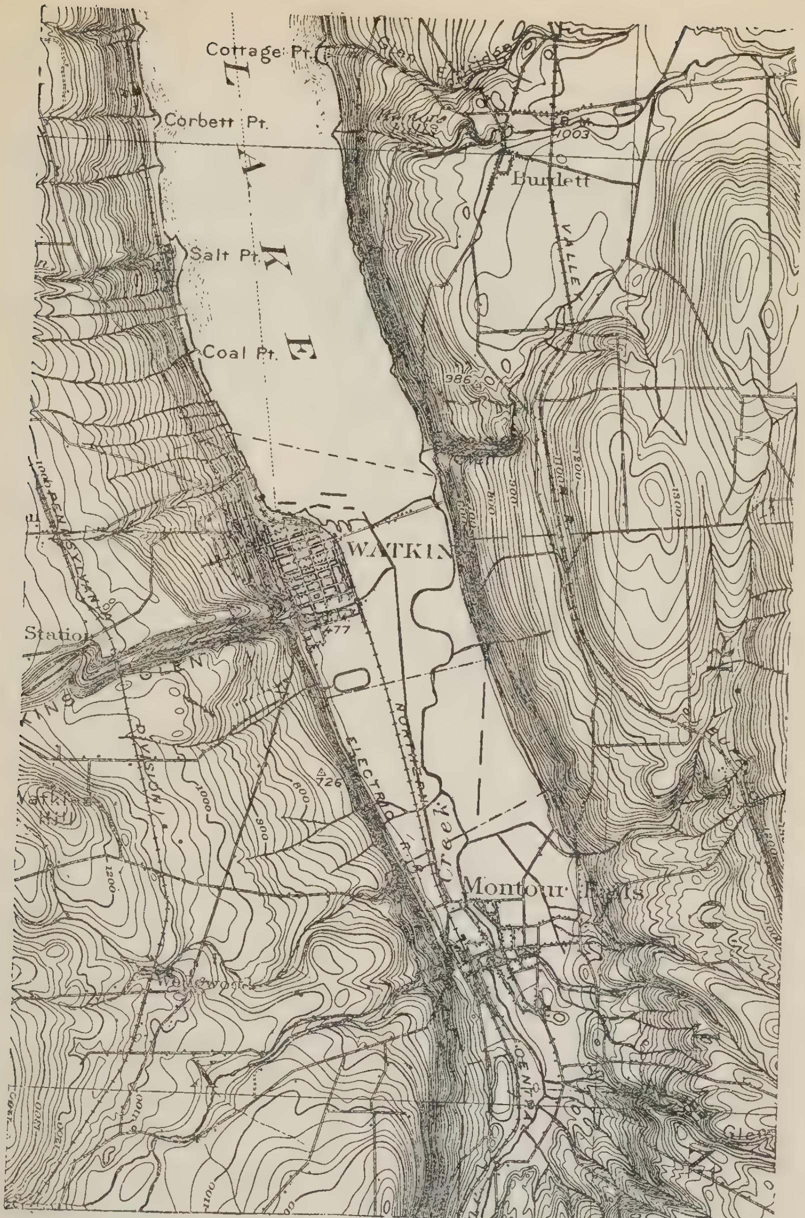


FIG. 4.—Detrital filling at the head of Seneca Lake

and subdued the State to the same condition that Greenland now suffers.

(6) In the waning of the Quebec Glacier and the recession (northward) of its south front, it served as a barrier in all of the north-sloping valleys. Glacial lakes were thus held in all the valleys, and the present lakes are lineal descendants of the ice-bound lakes.

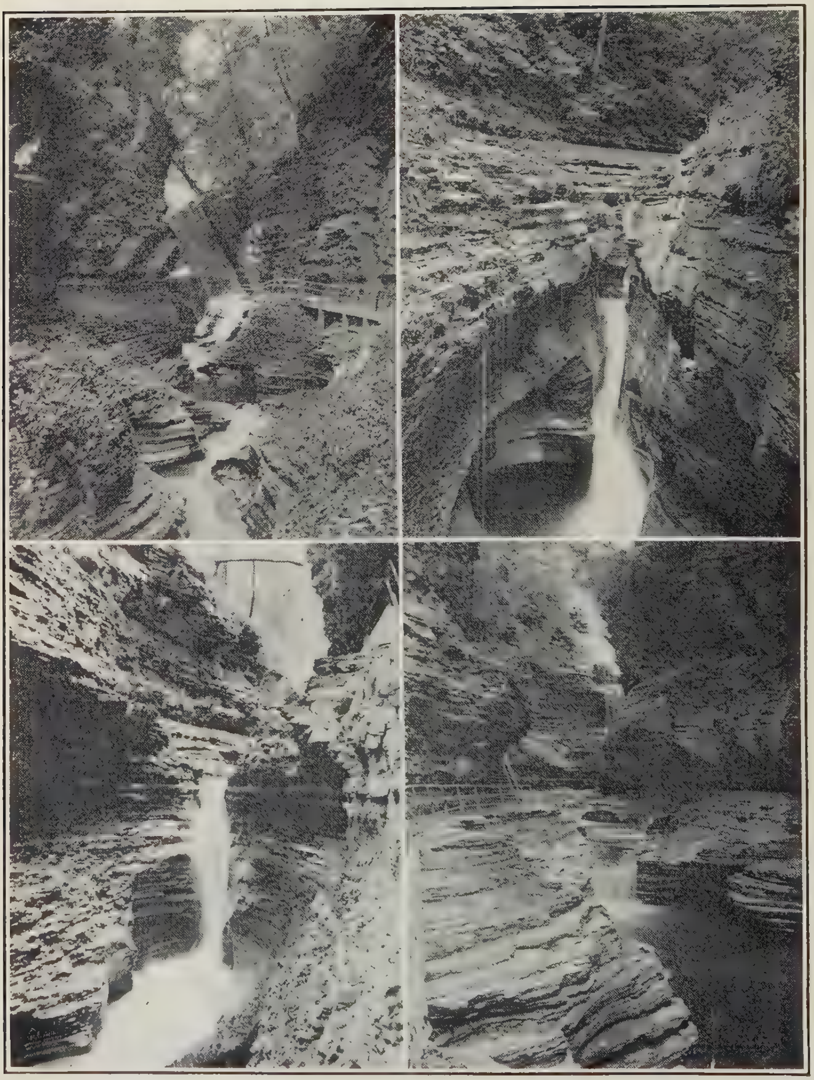
(7) During pauses in the recession of the ice front the heavy load of rock rubbish was piled in the valleys. One great series of these frontal moraines is the heavy fillings south of the lakes. Another forms the wide plain that buries the north ends of the valleys and produces the lake basins. (See fig. 2.)

(8) Northward uptilting of the land since the weight of the ice cap has been removed has lifted the north ends of the lakes, thus producing some increase in their depth.

(9) The filling process, by inwash of detritus and the accumulation of peat, has already obliterated some of the shallower lakes, and has made a beginning on the destruction of the remaining lakes. Witness the extensive plains at the heads of Canandaigua, Seneca, Cayuga, and Owasco Lakes. (Fig. 4.)

LAKE KEUKA

View of West Fork looking north—Characteristic topography of the Finger Lakes Valleys



WATKINS GLEN

(Photograph by A. J. Newton)

CAVERN CASCADE, WATKINS GLEN

(Photograph by C. A. Payne)

CHEQUAGA FALLS

In glen of Montour Falls, head of Seneca Valley

ITHACA FALLS

Below the campus of Cornell University. (Photograph by Ithaca Engraving Co.)

TAUGHANNOCK FALLS

East side of Cayuga Valley, 9 miles north of Ithaca. The highest cataract in the eastern United States. (Photograph by Ithaca Engraving Co.)

FOSSIL MARINE FAUNAS AS INDICATORS OF CLIMATIC CONDITIONS[1]

By Edwin Kirk

U. S. Geological Survey

Since the conception of an earth gradually and appreciably cooling within the space of geologically recorded time has been changed so radically, a great deal of interest has been manifested in collecting evidence as to what the climates of the past may actually have been like. No longer do we vision the tepid waters and steaming air of the Carboniferous swamps pictured in the geologies of a generation ago. Rather we think of that widespread glaciation of the Permian or upper Carboniferous and the constantly augumented series of glaciations reaching down from the pre-Cambrian to the present. To be sure, most of us are subconsciously superimposing these glacial periods on a mental background consisting of a warm genial world and warm oceans. They are therefore incomprehensible anomalies, only to be explained by fundamental changes such as shifted poles, reversed oceanic currents, or similar abnormal conditions. We have, it is true, indubitable evidence that secular changes of climate have taken place, but one who chose could well argue that we have no conclusive proof that the mean annual atmospheric temperature at sea level or the mean temperature of our oceanic waters has changed notably during recorded time. Changes in elevation and in the relative distribution of land and water, with the important corollary of changed oceanic currents, may well account for the climates of the past, as has been ably advocated by many geologists from Lyell to the present. The purpose of the present paper is not to controvert any one of the multitudinous speculations in regard to the climates of the past but briefly to submit a few facts in regard to one line of evidence used by the majority of the speculators.

Among most of the writers so vividly depicting the equable climates widely prevailing during the Paleozoic the widespread invertebrate faunas of the ancient seas offer a most conclusive argument for warm ubiquitous shallow seas and an accompanying world-wide sub-

[1] Published by permission of the Director, U. S. Geological Survey.

tropical climate. Such a concept best finds expression in the extreme case of those who argue for lack of solar control of climates until the Pleistocene. So, too, we have papers dealing with temperature conditions as evidenced by marine invertebrates. Barren shales have been pointed out as indicating deposition in cold uncongenial waters. In all cases the assumption is that abundant marine faunas flourish only in warm waters, and cold waters leave their record in sediments containing depauperate scant faunas, or destitute of life.

This viewpoint is interesting as a heritage from the past but is scarcely a credit to the present generation for whom the vast storehouse of information in regard to the life of the present seas and oceans is readily available. As a matter of fact the commonplace knowledge of present-day marine bionomists runs practically counter to current geological thought. Quotations from three recent works on oceanography will serve to sum up modern information on this subject.

In James Johnstone's A Study of the Oceans, 1926, page 138, we read:

> Particularly we may note that wherever there is sea there is also abundant life. * * * The sea everywhere in the Arctic and Antarctic regions is teeming with life—for instance, the extraordinary abundance of whales and seals in both Arctic and Antarctic seas before the ruthless slaughter initiated by modern industrialism began. Even now the incredibly great wealth of bird life in the Antarctic, as seen in the penguin rookeries, is an extraordinary thing. In the sea itself animal life of all kinds, both in the surface waters and on the bottom, is more dense in the polar regions than it is in the intertropical ones.

From J. T. Jenkins's A Textbook of Oceanography, 1921, we quote the following on page 53:

> The main source of organic material in the sea is fortunately met with in cold-water areas.

On page 98 he says:

> Generally speaking, the open oceans are less rich in plankton than coastal waters; again, tropical seas are poorer than colder waters and this is directly dependent on the amount of vegetable food in the ocean.

Indeed, the warm blue tropical water's are notoriously so poor in plankton that we find oceanographers commonly stating that "deep blue is the desert color of the deep sea."

In James Johnstone's Conditions of Life in the Sea, Cambridge Biological Series, 1908, pages 201 to 205, the comparative abundance of life in cold and warm waters is discussed. He says in part:

> The usual picture we obtain from records of voyages in tropical seas is that of the wealth of life, and we are naturally surprised to find that the tropical seas are not more abundant in plant and animal life than the temperate and polar waters; and, indeed, that the reverse is really the case.

There is little doubt that the distribution of life in the sea is exactly opposite to that on the land.

Again,

Thus, the colder seas are richer in life than the warmer ones; or at the very least the amount of life in polar seas is not less than in the Tropics.

My own attention was attracted to the subject when cruising in the cold waters of southeastern Alaska. Here in fiords and channels where in midsummer icebergs were usually in sight there is an amazing abundance and diversity of marine animal and plant life. Usually the waters teemed with medusae, some with tentacles 10 to 15 feet or more in length. Looking down through the clear waters the bottom was seen at times to be covered with colonies of huge multicolored sea anemones, great patches of echinoids, starfish, great numbers of large crabs, and innumerable smaller organisms. Going aboard a trawler bringing halibut and other fish up from depths of 100 fathoms and over, large numbers of worms of various sorts were found attached to the fish, while ophiuroids became entangled in the lines by the hundred. Occasionally large pectens, holothurians, and branches of coral are brought up from these depths. Myriads of shrimp are also known to be present. In shallower water I often dislodged one of the great laminarians from its anchorage and with the stem running through my hands brought into the boat the bowlder attached to the roots. On the rock and among the roots an amazing diversity and abundance of life was found. Ophiuroids, starfish, brachiopods, chitons, gastropods, Crustacea of various sorts, and pelecypods were the most common types. Often 20 or 25 species of invertebrates could be found on one bowlder 8 or 10 inches in diameter with its attached roots. As a commentary on the findings of future paleontologists investigating these deposits, it may be noted that a considerable number of the bowlders brought up were glaciated and were doubtless derived from present-day bergs. The present bottom sediments of the southeastern Alaskan fiords if preserved as sedimentary rocks would doubtless have all the characteristic features, in places at least, of tillites. In the sediments, however, would be found an abundant fauna. Along the shores between tides and just below low-tide level in most places the rocks and bottom are covered by innumerable echinoids, chitons, gastropods, Crustacea, and other invertebrates. Wherever there is a firm bottom not too deep the water is dark with algæ. Of the nekton, whales were seen daily, while porpoises, orcas, and seals were abundant. Of fish, myriads of herring and the vast migrating streams of salmon are well known, not to mention the sharks and deep-water halibut, cod, and red snappers. Only in Glacier Bay was marine life notable by its rarity. Swept out of the bay by the last advance of the ice, the front of which probably stood at the entrance to Icy Strait less than 200

years ago, the repopulation of the bay is under way. Most of the life is plankton and nekton. That it is abundant is evidenced by the swarms of cormorants, gulls, puffins, and other birds feeding among the drifting bergs and ice cakes. There is no doubt but that littoral life will again be abundant, and the beginnings have been made, chiefly by algæ, even as reforestation is taking place over the recently glaciated shores of the bay.

The abundance of marine life in high latitudes has long been known. So far back as 1852 in Sutherland's Journal quite an account is given of the fauna captured in the shallow waters of the far north with crude dredges. Most of the animals were dredged in waters up to 20 fathoms in depth and north of 74°. Temperature of the water as given in Volume I, page 321, never rose over 30° F. Thus near Beechey Island the fauna is described as consisting of "myriads" of sea urchins and ophiuroids, sea anemones, abundant crustacea, nullipores, *Mytilus* (?), Serpulæ, and diatoms. Near Cornwallis Island were found abundant fish, mollusca, ophiuroids, holothurians, infusoria, diatoms, and great amounts of seaweed. In Volume II, page 289, the variation of the fauna with depth is discussed. At 5 to 10 fathoms Mollusca are most abundant, then Echinoderma, then Crustacea. At 20 fathoms Echinoderma (Echinoidea) are most abundant, then Crustacea, and finally Mollusca. In 20 fathoms *Balanus* an inch in diameter was found. In the appendix to the Journal, pages CCI et seq., a list of the invertebrates is given. Not taking into account the annelids or microscopic forms a total of 48 genera with 68 species is listed. According to the classification of that time there were 8 genera of Gastropoda, 11 genera of Pelecypoda, 3 genera of Cephalopoda, 17 genera of Crustacea, and 9 genera of Echinoderma. This list does not cover the collections made, and these in turn, due to their casual character and the crude equipment used, probably represent but a small part of the actual fauna living in these far northern waters.

A more comprehensive idea of the faunas at present living under what are commonly supposed to be highly uncongenial temperature conditions is to be found in the reports of the British National Antarctic Expedition of 1901–1904, Natural History, Volumes II–VI, and the British Antarctic Expedition, 1907–1909, 1914. Most of the invertebrates were dredged through holes in the ice on the margins of the Antarctic Continent. In the National Antarctic Expedition, Zoology and Botany, Volume III, pages 1–10, the conditions under which the dredging was done are described. For a part of the time (June–October) ice crystals formed on the dredge cable for a depth of 5 to 8 fathoms and one time to a depth of 17 fathoms.

During this period the water temperature dropped to −2° C. (28.4° F.). The highest water temperature (at the end of December) was 30° F. The annual range of temperature was thus less than 2° F. and at all times below the freezing point of fresh water. Coupled with these temperatures the fact that the surface of the sea for much of the time was covered with thick ice gives us about as uncongenial conditions as one could wish. In spite of these handicaps life is abundant—far more so than in many tropical and subtropical seas. A fairly careful check of the reports of the National Antarctic Expedition gave a count of 275 genera and 455 species, not counting plants, vertebrates, worms, or minor types.

The following brief summary gives a rough idea of the more important types of organisms represented and the relative abundance in terms of genera.

Coelentera	44 genera.
Tunicata	25 genera (south of 60°).
Porifera	17+ genera.
Echinoderma	25 genera.
Mollusca	44+ genera.
Brachiopoda	1 genus.
Crustacea	84+ genera.

The zoological collections of the British Antarctic Expedition (Geology, Vol. I, 1914) were obtained in part from material dredged through the ice in McMurdo Sound and Ross Sea (about 78° S.) and in part from the upthrust muds of the shores. A brief summary is here given of the fauna as found in this region.

FORAMINIFERA

Twenty-four species were collected, of which 12 have been found on the subantarctic islands of New Zealand. "Foraminifera evidently abound in Antarctic Seas." "In the case of the raised marine deposit near Mount Larsen, the well-known *Biloculina* are so abundant as almost to constitute Biloculina clays, like those so well known in the neighborhood of the Arctic Circle."

PORIFERA

"Sponges were wonderfully abundant, so much so as to be quite important contributors to the muds and oozes forming at present at the bottom of McMurdo Sound and Ross Sea." "These siliceous sponges frequently attain a very large size, of from a foot to one and a half feet in diameter."

COELENTERA

One calcareous cup coral was found in the upthrust muds.

ECHINODERMA

"Echinoderms were extraordinarily abundant. On looking through the clear ice one could see that the sea bottom was almost completely covered in places with echini."

OSTRACODA

"Ostracoda were also abundant in the raised marine muds."

MOLLUSCA

"Mollusca are well represented by several forms of which the more important were an *Anatina* and *Pecten colbecki.* The large gastropod *Neobuccinum* must occur in great numbers * * *." The pectens were nearly 4 inches in width, and hundreds of valves were found in the upthrust muds.

The following Mollusca were collected in the upthrust muds:

Chitons.	Valvatella crebrilirulata.
Pecten colbecki.	Lovenella antarctica.
Thracia meridionalis.	Lepcta antarctica.

MISCELLANEOUS

In addition to the above invertebrates, brachiopods (Lyothyrina), Polyzoa, starfish, ophiuroids, and holothurians are mentioned as being common.

DIATOMS

"An extremely important constituent of all these muds are of course the diatoms. In fact, of all the organisms which have been mentioned, it appears to us at present that probably the most important contributions to the organic deposits on the floors of these seas are the diatoms, the siliceous sponges and the foraminifera." In addition to the marine diatoms there are vast numbers of fresh-water diatoms on the continent itself.

Vastly more data of the same sort as that given above could be brought forward both as regards the Arctic and Antarctic marine faunas and floras as well as cold-water life elsewhere. Anyone caring to pursue the subject further can consult the numerous reports of expeditions to the far north and south.

As is natural, it appears that the most important factor conditioning the well-being of marine animals is that of food. As shown in the ultimate analysis, the problem of food resolves itself into the presence or absence of phytoplankton. In the sea, microscopic plants furnish food to the smaller invertebrates, which in turn are eaten by higher organisms, or the plants themselves may serve directly as food

for the higher types of invertebrates and even some of the vertebrates. The abundance of the phytoplankton, in turn, is dependent on the presence of a long list of chemical elements in the sea water. It seems to have been shown that of these the presence or absence of nitrogen is the most critical factor, the other elements being more stable and of more universal distribution. Analyses have shown a low nitrogen content in many of the warmer sea waters, probably due to the greater activity of denitrifying bacteria. Here we seem to have the explanation of the relative scarcity of life in some of the warm-water regions. Apart from the factor of food, marine life thrives in varying degrees under widely varying conditions of temperature, salinity, light, pressure, and mechanical stress. Extreme variation from the average of any of these factors is harmful but seldom under natural conditions prohibitive. It is a constant source of surprise under what uncongenial conditions animals of some sort will thrive and multiply. Too little account is taken of the great adaptability of organisms to changing environment when plenty of time is allowed.

It is of course not possible to solve the problem of barren sedimentary rocks of the past by any general formula. Apart from food, the presence of oxygen, reasonably clean water, and the absence of positively poisonous substances are perhaps the most important requirements of marine animals. In semilandlocked basins, or those having a threshold barrier making for poor water circulation, lack of oxygen may obtain, or the generation of sulphureted hydrogen from the decay of organisms may render life on the bottom impossible except for bacteria. Such conditions are found in the Black and Caspian Seas as well as in some of the Norwegian fiords. As a matter of fact perhaps the greater part of the barren shales may most readily be explained as the result of foul water. Muds within the zone of wave action, that is, approximately 100 fathoms, are kept more or less stirred up and in a partial state of suspension. This is a condition under which few animals can survive. At any rate I think we may safely assume that cold climate has a very remote chance of having a great deal to do with the lack or rarity of marine life, and even water temperature is not a critical factor.

There is at present one outstanding difference between cold and warm water faunas. This is that despite the great abundance of individuals in cold-water faunas the number of species is relatively less. Of how little use this criterion is in evaluating a faunule of the past may be judged by considering the fauna of the Antarctic. With its 275 genera it is sufficiently rich to compare favorably with any fossil fauna, and even eliminating the soft-bodied types which are seldom preserved in the rocks it still does very well. In this

connection it is interesting to note that the wide ranging faunal units of the Paleozoic are very remarkable in the fact that they are made up of large numbers of individuals representing relatively few genera and species. In western America a certain Ordovician horizon may confidently be expected to yield a dozen or so genera of brachiopods and corals, in most cases represented by one species each. This small group of organisms is found in abundance from the Mexican border to central Alaska. Over and above this small number of characteristic species additional forms may only be added by diligent search. The wide range of the faunule is shown by the fact that the same approximate association of identical or nearly allied species is found in the Baltic region of Europe, in Baffin Land, Ellesmereland, and Burma. Similar small groups of widely distributed organisms are found at many other horizons.

Under present oceanic conditions organisms secreting large amounts of lime are most abundant in warm waters and minimal in very cold waters. This is perhaps a function of the chemical content of the sea water, depending on the amount of carbon dioxide present. Here we are at a loss, for who knows the gas content of the ancient seas? Even at that, heavy lime secretion is not characteristic of the Paleozoic organisms as a rule, particularly in the early Paleozoic. Judged by such a standard, certainly the marvelous assemblage of soft-bodied invertebrates from the Cambrian shales of British Columbia described by Walcott would point rather to cold than warm water conditions. In this connection it should be borne in mind that the calcareous alga *Lithothamnium* is extraordinarily abundant in the north polar sea, where the temperature of the water seldom rises above 0° C. After all we are not seeking to prove freezing temperatures for all our ancient faunas. Rather the attempt has been made to show no real incompatibility between our fossil faunas and a possible temperate to cold water habitat.

An argument for warm seas constantly used is the presence of coral reefs in the past. These reefs are not impressive at best and should be used with caution. Bonney, Yakolew, and others have pointed out that there is little real analogy between Paleozoic and recent coral reefs. As a rule the most important constituent of the Paleozoic reefs is Stromatoporoidea, while next in importance come the Tabulata and finally the Tetracoralla. These proportions vary, but as an average they probably hold good. Of the three groups the Tetracoralla alone may be compared with the reef corals of to-day, and even here the kinship is so remote that it would be rash indeed to insist on similar conditions of life. Rather, it is better to consider the bathymetric and temperature ranges of modern corals. We have already noted the presence in the freezing waters of McMurdo Sound of a cup coral, and we know that similar corals range down

to a depth of 5,000 meters. Of even greater interest is the presence of large numbers of colonial corals along the European coast. The distribution of these forms has been summarized by Pratje ("Korallenbänke in tiefem und kühlem Wasser," Centralbl. für Min. Geol. u. Pal. 1914, No. 13, pp. 410–415). He shows that the four species belonging to the genera Lophohelia, Amphihelia, and Dendrophyllia referable to the families Oculinidæ and Eupsammidæ are living to-day as far as 71° north latitude. Off the coast of Norway the bathymetric range of the corals is from 200 meters to 600 meters. Off the Irish, French, and Spanish-Portuguese coasts the optimum depth appears to be somewhat the same, but a downward range to at least 1,800 meters is known. The seaward range of the corals seems to coincide approximately with the edge of the continental shelf. Off the Norwegian coast with an adverse factor of high salinity the northern limit seems to be conditioned by low temperature. The minimal temperature, however, is 6.6° C. If the Tetracoralla and Tabulata of the past must be considered as requiring temperature and bathymetric conditions like those of present-day corals, we have a wide range of both to choose from.

We may now fairly ask the question whether marine animals are dependable indicators of the climates of the past. I think this can safely be answered in the negative. Most writers consider warm climates and warm oceanic waters inseparable, and likewise bracket together cold waters and cold climates, overlooking the well-known examples of relatively warm waters along coasts in high latitudes and cold waters along tropical coasts. Thus the present-day tropical climate of coastal Peru, judged by its sub-Antarctic seals, penguins, and other cold-water types, would almost certainly be classed as at least cold temperate if judged by its fossils. Putting aside atmospheric temperatures, can we even make accurate temperature readings of the waters of the ancient seas? Here the factor of depth confronts us, but even assuming that all our seas were shallow and devoid of currents I still do not think our best efforts in this direction would be more than a guess except possibly in the case of our later fossil faunas. Life is capable of almost infinite variation and adaptation. Thus we see animals changing their habitats from salt to fresh water or from normal salt to highly saline water, from water to land or from land to water, from cold to hot and from hot to cold, in most cases when living in the same medium and without marked structural modifications. As to the evidence to be adduced from wide distribution the modern cool and cold water faunas of the Southern Hemisphere are quite as widely spread as our Paleozoic faunas of the Northern Hemisphere. Some of the Antarctic species are even found in the Arctic seas. Distribution after all is primarily controlled by available routes of travel.

PALEONTOLOGY AND HUMAN RELATIONS[1]

By Stuart Weller

It is my purpose to-day to deviate somewhat from the usual custom of speakers on occasions like the present. I shall attempt to present to you neither the results of research in which I have been engaged, nor an outline of the progress of the science which I represent, during the past year. I shall attempt, rather, to outline briefly a train of thought in which I have been interested for many years and which may have a somewhat more general interest than the presentation of a more technical subject.

Doubtless there is no topic which possesses a wider interest for members of the human race than the topic of man himself, and I have found during my 30 years of teaching paleontology that students of this subject are always deeply interested in any contacts which can be suggested or established between the problems associated with the extinct life of the earth and human affairs.

To the average person the word " fossil " conveys the impression of something dead, something so absolutely dead as to be beyond all possibility of resuscitation. It carries the impression of something that is unchangeable. The epithet " old fossil," when applied to a man, signifies the superlative of conservatism, a man so devoid of the possibility of change that he is mentally dead.

From a study of the fossil trilobite and brachiopod remains in the ancient strata of the earth's crust to a consideration of human relations in the year 1926 A. D. may seem to be a path of interminable length, but notwithstanding the remoteness of the time when the Cambrian faunas represented the life of our planet, or of the still vaster remoteness of the earliest ancestors of the Cambrian trilobites and their associates, there has been a continuity of life on the globe. Man himself has unquestionably arisen from a more lowly and less specialized ancestor than himself; this ancestor in turn looks back for his origin to still simpler forebears, and so on back and back into the long past periods of earth history.

It is the task of the paleontologist to carry on researches concerned with the extinct life of the earth, but the continuity of this extinct

[1] Presidential address, read before the Paleontological Society Dec. 28, 1926. Reprinted by permission from Bulletin of the Geological Society of America, vol. 38, Mar. 30, 1927.

life with the contemporaneous life, including man himself, seems to warrant making the attempt to find some lesson from the past for the guidance of the present. The word "history" as commonly conceived refers to human history alone; but, because of the unbroken continuity of events, the roots of all human history must lie far back in the prehuman periods. Just as the consideration of the morphological evolution of man leads us back into prehuman periods, so the evolution of man's social relations originates in the remote periods of the past, long ages before the appearance of man himself. These relations of the present with the remote past are too much overlooked by students of human history, every one of whom would be the gainer were he to possess at least some understanding of geology and paleontology. H. G. Wells seems to be the only historian, in the commonly accepted sense of the term, who has begun his story of humanity with a consideration of the prehuman inhabitants of our earth, and although his treatment of this phase of the subject is brief and somewhat distorted, it shows an appreciation on his part of the desirability of linking the events of the really ancient history of our planet with the modern or human phases of the subject.

The materials with which the paleontologist must deal are the dead, unchangeable fossils, dug up from the rocks of the earth's crust, but the problems which arise from the study of these materials are far from dead, being filled with living interest and giving real vitality to the whole field of historical geology. These now defunct fossils were once living, growing organisms, which were associated together in innumerable faunas, which lived in all portions of our earth, which followed one another in almost endless succession from the earliest recorded period of geological history to the present time, and which were adapted to all sorts of environmental conditions on the land and in the sea.

This inconceivably vast succession of life assemblages which has inhabited the earth has left, of course, only a meager record, and of the record which is preserved in the rocks only a small part is now or ever will be available to the paleontologist for study. This record, however, is a record of accomplishment. All of these prehuman inhabitants of the earth have been subject to the same laws of evolution, in all its aspects, that are directing the life of the present, and while the paleontological data are not subject to direct experimental study, natural experimentation has been in operation on a vast scale, some of the results of which are available for consideration.

It is not my purpose in this paper to discuss the bearing of these paleontological records on the morphological evolution of man, but rather some of its bearings on human relations. In all probability

the human species will undergo little or no essential morphological change in the centuries and millenniums to come, while he is a resident on the earth. He may suffer the loss of certain minor parts through disuse, but in all probability the man of the year 1000000 or of 10000000 A. D. will be essentially what he is to-day as regards his physical form and organization. Man has become the master of his environment, and because of this he is able to adapt himself individually to almost every condition on the face of the land and of the sea, and with his mechanical devices he even penetrates the air itself and the depths of the ocean.

Notwithstanding man's control over his environment, his social organization is far from complete; it is, in fact, so entirely out of adjustment that warfare and strife between all sorts of groups is continual. It must be recognized that, geologically speaking, man is in his infancy. He has been a resident of the earth for perhaps one-half million of years—a short time geologically—and for 475,000 or more years of this time he led an existence but little different from that of his other animal associates. The gradual attainment of environmental control doubtless was the real reason for his recent rapid advancement, and it has been only a few thousand years since he began to live together in large communities, where the necessity for elaborate social organization has become imperative. The human generation is a period of 25 or 30 years; about three or four generations in one century, 30 or 40 in a thousand years. Our ancestors had scarcely emerged from the condition of savagery 2,000 years ago, less than 100 generations. When we look into the future our expected existence is measured, not by scores or hundreds of generations, but by many thousands, and during all of this period the laws of evolution will continue to act and our social organization will become more and more perfected.

The paleontological record is a vast sociological as well as a morphological record. The organisms of the past have lived in faunal assemblages comparable in a way with the groups of complex human societies of which we are a part. This life record is the exemplification of a great sociological experiment, the consideration of which should be full of suggestion to the student of present human social relations. The parallels between the history of the extinct fossil faunas of the paleontologist and the human social groups are many. Numerous provincial faunas are recognized, more or less completely isolated from other contemporaneous faunal groups, by reason of a lack of means of intercommunication. Certain human societies likewise are, or have been, conspicuously provincial in character, and this provincialism is due to the same cause, namely, a lack of the means of communication. A mountain range or a great river,

in the past, have been effective barriers which have prevented the intermingling of groups of peoples. These groups may have originated from the same stock, but, lacking contacts one with the other, they have developed differently and finally have come to exhibit conspicuous differences.

Most of the organisms whose life records have been preserved in the rock strata were creatures whose existence was spent in an aquatic environment, because the most of our fossil-bearing rocks are consolidated sediments which were laid down in water. Furthermore, by far the most of these aquatic sediments, with their inclosed remains of once living animals, are marine in their origin. Likewise most, if not all, of our marine paleontologic record is of comparatively shallow-water organisms. The pathways along which means of communication have been established for such shallow-water marine life are wholly different from the lines of communication suitable for land-living creatures such as men, but the relation of lines of communication to the faunal or social evolution of these creatures themselves is the same. Among the creatures of the past, at times when environmental conditions approached uniformity throughout large portions of the earth and when pathways of communication were relatively open and continuous, a tendency toward the development of widespread, more or less uniform faunal assemblages existed, although at no time did such conditions become sufficiently perfected or continue unbrokenly for long enough time to permit the establishment of a truly world-wide, cosmopolitan fauna. The Silurian faunas of North America and northern Europe possess many common characteristics, showing beyond question that some pathway of shallow marine water communication existed during that period which permitted the creatures inhabiting these widely separated seas to intermigrate from one region to the other. During a portion of Mississippian time the marine faunas of central North America and those of northwestern Europe possess much in common, to account for which some pathway of intercommunication must be assumed to have been in existence. Many other examples of close similarity between extinct contemporaneous marine faunas, in widely separated portions of the earth, are well known, and the existence of such similarities is uniformly accepted by paleontologists as evidence for the existence of some pathway of communication between these distant localities.

Likewise the animals and plants which have lived on the land have shown relationships over widely separated geographic areas at certain periods. During upper Miocene time the land mammalian faunas of North America and Europe are known to have included so many closely related forms that the only possible explanation of the situa-

tion is the assumption of the existence of a so-called land bridge over which these creatures could pass. As the existence of such a line of communication could only have been in the far north, we are forced to the conclusion that the climatic conditions of the period were much different from those which now obtain. At this time the primitive horses seem to have migrated from America to Europe, while the primitive elephant-like mastodons found their way from Europe into America. Many other mammalian types, including members of the rhinoceros and tapir families, are also common to the two continents at this time.

During Carboniferous time the plant life of North America and Europe possessed many common characteristics. Many of the same genera and the same species are recognized in the fossil floras of these widely separated regions, and they could only have had such geographic distribution with lines of land communication somewhere between the two continents.

Some periods in geologic history show notable provincialism in the development of life on the earth. The northern and southern American continents were essentially isolated, so far as their land life was concerned during much of Tertiary time, known as the age of mammals, so that in South America, especially, a notable provincial land fauna developed. About the beginning of Tertiary time there seems to have been a limited connection between the two continents, following which isolation of the southern continent is believed to have been complete until Miocene time, when a few of the peculiar southern types began to filter through into the more northern continent.

The most isolated continental area of the present time is Australia, and because it has lacked any land connections with other continents for so long a time, it has come to be inhabited by a most peculiar, provincial land fauna. If means of communication between Australia and its neighboring continents had existed, its marsupial fauna undoubtedly would have been much modified and perhaps completely exterminated by the more advanced mammalian types.

During Devonian time a number of distinct marine faunal provinces are known to have existed within the limits of the North American Continent, each one inhabited by an assemblage of creatures distinctly different from those in another province not greatly removed geographically, but separated, nevertheless, by a barrier which was insurmountable to the creatures whose fossil remains we now dig out of the rocks. With changes in the course and positions of the strandlines of this period, notable changes in the distribution of the faunas themselves came about. The story of the faunal changes and migration of this ancient Devonian life, read from the paleontological records in the sedimentary rocks, is as fascinating as the

story of the migrations of human races. Indeed, the analogies between the human record and the paleontological record are really amazing.

The Cuboides fauna of late Devonian time appeared suddenly in the paleontological record of the eastern interior region of North America. No occurrence of any possible ancestral forebears of much of this fauna is known in the sediments immediately preceding the Tully limestone in New York, in which the Cuboides fauna is typically represented. These strange, new forms could only have originated in some more or less distant province which had been long separated from this eastern American basin, the isolation associated with different environmental surroundings being responsible for the differences in contemporaneous provincial faunas. Finally, on the culmination of slow and gradual changes in the strandlines, and perhaps in other changes, a shallow-water pathway of communication was established between the home province of the Cuboides fauna and eastern North America, and the migration was permitted which gave rise to the sudden appearance of the fauna where we now find its paleontological record.

How similar is this discovery of a new province and a new outlet for the expansion of the Cuboides fauna to the discovery of the American continents by the European white races a little over 400 years ago. Men had long sailed ships on the sea and had traveled from place to place along the Mediterranean and European shores. The first crude boats were propelled with oars; later, sailing vessels were invented and use was made of the driving force of the wind. Early sailors could not venture out of sight of land without danger of becoming lost. Then they held their courses, directed by the heavenly bodies, and finally the magnetic compass was discovered. This was a long, slow process, comparable to the slowly changing strandlines of the geologic past. Finally one man, more venturesome than the others, sailed away from the European shores into the unknown ocean to the west. He discovered a new continent, just as the Cuboides fauna discovered a new province in America. When once the way was pointed out, other adventurers followed, and ere long a continuous stream of white Europeans was flowing across the Atlantic.

The aboriginal peoples of our continent are comparable with the faunal predecessors in eastern North America of the Cuboides fauna. The differences between the European white races and the original Americans were as great, humanly speaking, as were the faunal differences between late Middle Devonian life and the Cuboides fauna. In each of these migrations the newcomers overran the new fields into which they entered, driving the older occupants into extinction

or absorbing them into their own social organization. Geologically speaking, the change from the old order to the new, in each case, was essentially instantaneous. As soon as the pathway was established the change was complete. The few centuries which have been required to transform America from the Stone Age culture of the Indians to the age of skyscrapers, railroads, automobiles, and radio are absolutely negligible in geological history. The change has been as abrupt as the sudden change of fauna in passing from one sedimentary bed to another conformably overlying it in which the paleontological record is almost totally different.

Other analogies between human history and the paleontological record are not wanting. In late Devonian time a series of faunal migrations from the Eurasian Province into North America are recognized. First came the Cuboides fauna already mentioned, which is typically represented in the Tully limestone of New York. A little later came the Intumescens fauna of the Portage beds, and this in turn was followed by the *Spirifer disjunctus* fauna of the Chemung formation. This succession of waves of migration of long extinct marine life may be compared with the successive waves of migration of the uncultured tribes of northern Europe into the confines of the Roman Empire to the south. The causes of these two series of migrations, one of the more primitive life of Devonian time, the other of human races, was essentially the same—first, the discovery in each case of the pathway along which the migration could take place, and, second, the crowding of the developing life in the original home province.

Without doubt, the most notable development in human history during the last 500 years has been the discovery and occupation of America by the white races of Europe. The difference in cultural development between the immigrant race and the aboriginal Americans was so great that all opposition to the newcomers was essentially negligible. The more or less crowded peoples of Europe were set free into an essentially unoccupied territory of vast extent, in which opportunity was afforded for expansional development on a far grander scale than during any similar event in all recorded human history. This opportunity for expansional social evolution is doubtless the primary cause for the rapid development in science and invention which has made the last few centuries so notable.

Similar expansional evolutions have taken place among both marine and land faunas of the past. During periods of rising sea level relative to the land surface great areas of the lower portions of continental surfaces have become submerged and transformed into the bottoms of more or less widely extended shallow seas. In such situations the life of the shallow seas adjacent to the expansions has been freed from its more severe struggle for existence and has been

able to expand with the increasing territory suitable for its living conditions, the struggle becoming less severe between individuals and species and more a struggle between the living creatures and their environment, resembling in this respect the struggle of the early pioneers with the new American environment. A notable example of the expansional evolution of marine life under a situation such as that just mentioned is shown in the crinoidal faunas of early Mississippian age in the interior of North America. The rapid evolution of these organisms at this time led to their deployment into a greater number of genera and species than are known elsewhere in the paleontological record. From the interior province of North America as the original home of this fauna, it spread outward into distant parts of the world, the generic and specific representation becoming more and more attenuated as distances were increased.

Examples of the migratory wanderings of the now extinct faunas of the past could be multiplied almost indefinitely, but in no case is there a record of a truly world-wide, cosmopolitan fauna, either of the land or of the sea. What has hindered such a development has been the dependence of these living groups of organisms on their environmental conditions. Had a time ever existed in the past when the conditions of temperature, purity of water, salinity, and other environmental factors had been uniform throughout the whole of the shallow marine waters of the earth, and at the same time had there been free means of communication between all of the shallow waters, no paleontologist can doubt that a uniform, world-wide, shallow-water marine fauna would have sprung into existence. The two factors controlling such a development are environment and the paths of communication. Perhaps a lesser degree of uniformity among the land-living creatures of the past has obtained than among those of the marine waters, for the reason that differences in environment are perhaps generally more sharply limited on land than in the shallow marine waters. The earthly habitat where the most uniform environment exists to-day is found in the abysmal depths of the ocean, and the life of these cold and dark abysses is essentially the same in all oceans.

In the application of these factors of environment and communication to man's distribution and social organization throughout the world may we not look forward to results similar to those exhibited among the more lowly creatures whose recorded history carries us back for some hundreds of millions of years. In so doing the factor of environmental control may be largely or wholly disregarded, because man has been able to adapt himself to all sorts of terrestrial environment. Upon these conditions the factor of communication becomes dominant.

When man was limited to his own physical efforts for means of communication from place to place, all sorts of barriers confronted him on every side. The residents of one continent were almost completely isolated from those of every other continent, and consequently their evolution progressed along wholly independent lines. Many physical features within the continents themselves were almost as insurmountable barriers as were the oceans separating the continents. Under these conditions the races and tribes of men developed extreme provincialism, just as did the faunas of the past under the conditions of isolation.

During the past few centuries conditions making for human provincialism have been disappearing with accelerating rapidity. No corner of the earth is out of touch with the rest of the world at this time. Men have visited both the North and the South Poles. A trip around the world is of less moment to-day than a voyage across the Atlantic Ocean a few years ago. With the development of rapid transit through the agency of steamships, express trains, automobile, and airplane, man can transport himself anywhere, and with the telegraph, telephone, and radio he can communicate instantly with his fellows over vast distances. Under these conditions do not the paleontologic lessons of the past warrant our reaching the conclusion that unity and uniformity may be attained in the social and political organization of mankind in the not-distant future, judging from the time standards of the geologist?

The human race is in its infancy; it is just stepping over the threshold of its existence. The wars, the struggles, and the conflicts which engage us at this time are but the children's diseases of the race. Diseases of old age may come in the future, but these infantile ailments will doubtless be left behind. No paleontologist with his outlook on the continual forward-moving progress of living things of the past can fail to be an optimist in his outlook into the future.

While delving into the life records of the past, paleontologists have found that societies of organisms have been continually changing their characteristics; many forms and even large groups of organisms have passed into extinction; but with all of these changes there has persisted a continual forward progression. In the course of their evolution through the geological ages many groups of organisms have developed at some time in their history, along certain side lines of evolution, extravagant characteristics of ornamentation, apparently useless to the creatures themselves, which have culminated in the extinction of that particular phylogenetic line. A notable example of this sort may be found among the Lichad group of trilobites. These creatures make their first appearance in Ordovician time. In the faunas of this period they are characterized by the

presence of comparatively small tubercles and perhaps by a few short and slender spines. In the Silurian faunas they attain larger proportions and become more ornate, with numerous spines and tubercles of an extravagant sort. In our American faunas these Lichads culminate in the gigantic *Terataspis grandis* of the early Middle Devonian, a creature which attained a length of eighteen or more inches and which developed most elaborate spines, many of which bore secondary spines and tubercles. Altogether this creature must have been one of the most bizarre trilobites of all time. The Dalmanites also, another group of trilobites, originated in the Ordovician as small, unornamented individuals. In the Silurian they developed some degree of ornamentation, but in the Lower and lower Middle Devonian these ornamental characters attained the highest development and the creatures increased greatly in size. With the close of Onondagan time in America all of these gigantic and ornate trilobites became extinct, and from that time to the final disappearance of the whole class they were represented by small, unornamented forms which had persisted from early Paleozoic time without the development of such ornate features as were shown by their gigantic relatives.

Another group of organisms with a similar history are the chambered cephalopods. These started in early Paleozoic time with smooth shells and simple sutures. By the end of Paleozoic time some of them had developed fairly complex sutures, and some shells with nodes and ribs were in evidence. Associated with these were others with sutures as simple and shells as smooth as the oldest forms. The development of increasing sutural complexity and increasing ornateness of the shells continued through Mesozoic time, when nearly the whole group became extinct. The simple sutured, smooth-shelled nautilus alone survived, and it continues to live in the seas to-day as the only survivor of its race.

Additional examples, similar to those cited, could be suggested in other organic groups among both the invertebrate and vertebrate phyla of the animal kingdom. Indeed, it may be asserted with much certainty that the extravagant development of ornate characteristics is a condition preceding by no long period the extinction of the race so developing. Among living gastropod mollusks such races as Murex and its allies, which are highly ornate with spines and processes, are doubtless rapidly approaching their time of extinction.

May not these events in the paleontologic history of creatures of the past convey a lesson to the student of human relations? Human civilizations and social organizations have arisen in the past and have dwindled and become extinct, just as have the societies of prehuman inhabitants of our earth. Their places have been taken by other

social groups arising from more or less obscure sources. May not the underlying causes of the waning of both these sorts of societies be similar? Too great prosperity, perhaps, and the expenditure of vital forces in the development of ornamental characters not fundamentally of service to the race. And may not the general recognition of this lesson serve to guide, in some measure, the future destinies of humanity?

The suggestions which I have made by no means exhaust the parallelisms between the social organization of the extinct creatures of the earth and human society. Everyone who is familiar with the materials of paleontology can call to mind other comparable relations between these two social groups. I believe, however, that enough has been said to establish the fact that the dead, fossil organisms of the past can be shown to have a vital interest for students of living human society, and that these objects, long buried in the sediments of the earth's crust, can convey lessons to the present generation of men which may be of service in the guidance of our social evolution.

AT THE NORTH POLE [1]

By Lincoln Ellsworth

[With 15 plates]

Although exploration in general results in wide usefulness, the real excuse for "going exploring" is the attainment of knowledge for its own sake. While the practical man of affairs often considers any discovery of scientific interest only a waste of time and money, the world we live in is one of achievement, hope, and vigor, of new beginnings and enterprises in every field, because the explorer with his sextant and compass, the astronomer with his telescope, and the physicist with his miscroscope, venture out beyond the confines of dogma and conquer man's ignorance of "what lies beyond." In order to justify polar research, the scientific man will prefer to consider it in the light of other kinds of research, where the most fundamental and far-reaching discoveries of practical importance are sometimes made in the search for knowledge merely for itself.

At the North Pole is a huge tract of our globe practically unknown, and the conditions prevailing in it are unique. This alone should justify its exploration. To Roald Amundsen the investigation of this unknown area has always been a fascinating task. The two years of my association and companionship with him in our two voyages of discovery have been the happiest of my life.

The story of our first flight from Spitzbergen out over the Polar Sea to within 120 miles of the North Pole has already been told. After a journey lasting eight hours, the time estimated to bring us to the pole, we came down into the first open "lead" big enough for our airplanes to land in to take an observation as to our exact whereabouts, for we had been heavily drifted to the westward by a strong northeast wind, and by that time half our fuel was consumed. We found ourselves to be in latitude 87° 44′ N. and longitude 10° 20′ W. Thus, although we had flown 600 miles—the exact distance of the pole from Spitzbergen—our drift of 50 miles off our course

[1] Reprinted by permission from the Yale Review, Vol. XVI, No. 4, July, 1927. The photographs here reproduced, supplied by the author, did not appear in the Yale Review article.

was responsible for our loss in latitude and the exhaustion of the fuel necessary to carry us to the pole. Before we could get out, the lead closed up, and it required 25 days at hard labor to free one of our imprisoned planes. This, in short, was the history of the flight itself. The scientific results, from an expedition that cost $150,000, consisted in the exploration of 120,000 square miles of hitherto unknown regions and the taking of two soundings which showed the depth of the Polar Basin at that latitude to be 12,000 feet, thus precluding the likelihood of any land on the European side of the North Pole. But we had other compensations. We had blazed a trail, for the flight had shown that the meteorological conditions prevailing over the Polar Basin offered no hindrance to its further successful exploration by the proper kind of aircraft.

There were two things that greatly impressed me during this long sojourn near the pole. The first was the stability of the meteorological conditions in that isolated area—the winds blowing from the same direction day after day, with a velocity just sufficient to keep our Norwegian flag fully extended. The mean average temperature during the first two weeks of our stay was 10° below freezing, but on June 2, with the breaking of Arctic summer, the fogs descended on us, the thermometer rose to freezing and did not vary more than 4° during all the rest of our stay. Although the sun at that latitude—so close to the pole—maintained practically the same altitude above the horizon during the entire 24 hours, there was always a drop of a few degrees during the night period. The second thing that strongly impressed me was the manner in which we maintained our strength to do hard manual labor on a diet consisting of only liquid food—the equivalent of one half-pound a day per man of nourishment—a mug of weak chocolate morning and night and a mug of pemmican soup at noon. I could never count the three oat wafers which accompanied our mug of chocolate, for, although nourishing, they were of the size and consistency of the wafers that accompany a dish of ice cream in more civilized regions.

The mournful sound of the wind blowing through the rigging of our plane during our enforced stay made us quick to seek shelter in its interior after our day's labor of clearing away the ice. Although our four-walled compartment was of metal and heavily coated with hoarfrost, it shut out the damp, fog-bound waste in which we were but mites—a colorless waste that seemed to reach into infinity. The scanty heat from the "Primus," together with that given out by our bodies, was sufficient to raise the temperature above freezing. The hoarfrost, melting, dripped down our necks and spattered into our mugs of chocolate, but nothing could completely dampen our spirits, not even the thought of Riiser-Larsen's fast-diminishing stock of black chewing tobacco, which we were now smoking; for was not the

prospect of the warm sleeping bag, with the 10 malted milk tablets to munch contentedly as we dozed off to sleep and forgetfulness, that of heaven itself after the wretchedness of our waking hours? I never knew the real feelings of my companions, for whatever conversation there was, was mostly in Norwegian as we sat over our chocolate; but I learned to accept what each day offered. Spitzbergen was but eight hours away; maybe to-morrow we would be on the way! Thus passed our 24 ice-bound days, but on the twenty-fifth—the day we had actually set, two weeks previously, to start on foot for the Greenland coast, 400 miles away, which we knew we could not reach—our efforts to free the planes from the ice were rewarded, and one plane with six men in it rose and left that hell, forever.

Yet even after such an experience, we had not had enough. Our work was not yet finished. Beyond—to the northward—still stretched the unknown. Between the pole and Alaska lay what? Mystery—a mystery as luminous and yet as impenetrable as its own mirage—enveloped an area, on the Alaska side of the pole, twice that of the United States east of the Mississippi River.

For our next venture we decided to try an airship, knowing that Mussolini had one which appeared to fit both our needs and the size of our purse. This was the *N–1*, built to the designs of Col. Umberto Nobile in the Italian State Airship Factory, and christened by us the *Norge*, of semirigid construction, 348 feet long, with a displacement of 20 tons. Her fuel capacity of 7 tons, with which to run her three 250-horsepower Maybach motors, gave her a range of 3,500 miles without refilling, or about 70 hours, at a speed of 50 miles per hour. The *Norge* was equipped with a Marconi wireless direction finder, the tuning circuit for which was designed to cover a wide band of wave lengths; those used ranged from 900 to 1,400 meters. The energy for the specially constructed valve transmitter was delivered from a windmill-driven generator supplying 3,000 volts.

There was a delay of several days after the *Norge's* long flight from Italy to Spitzbergen, before she was able to proceed on her journey across the Polar Sea. Favorable weather conditions were essential. We needed a clear sky with good visibility, and a favorable wind; also a high barometric pressure and a low temperature. These last two elements influenced greatly the lifting capacity of the dirigible. For each degree Fahrenheit that the temperature went down, the airship gained 80 pounds in lifting capacity, which was increased with 140 pounds for each tenth of an inch added to the barometric pressure.

The keel of the *Norge* looked like a flying storehouse when all was ready for the start at 8.55 on the morning of May 11, 1926. The equipment included tents, sleeping bags, skiis, snowshoes for those who could not ski, rifles, shotguns, ammunition, a hand sledge—the

finest piece of workmanship I ever saw—made by Oskar Wisting on the *Maud*, and a big canvas boat. Two men among the personnel, Amundsen and Wisting, had the distinction of having been at the South Pole, and now both were en route for the North Pole.

Our provisions for the voyage consisted of pemmican, chocolate, oat biscuits, and dry milk, sufficient to last 16 men two months, with a daily ration of 500 grams for each man. On the walls of the cabin hung the pictures of Norway's King and Queen, which had been presented to the *Fram* expedition to the South Pole in 1910, an image of the Madonna, which the Italians had brought with them, and a four-leaf clover given to the ship by Major Scott, who piloted the British airship *R. 34* across the Atlantic. In the keel hung the flags of Norway, the United States, and Italy, to be dropped on the North Pole.

To those of us who made that first crossing of the Polar Sea it will ever be "life's great adventure," for in all human experience, never before has man traveled so fast and so far into the realm of the unknown. There is an indefinable something about such an experience, where illusion and reality are hauntingly intermingled, that may well color one's whole sentiment of existence ever after.

Two hours after leaving King's Bay we found ourselves over the "pack ice." What weather! The sun shone brilliantly out of a sky of pure turquoise, and the whalelike shadow that our airship cast beneath us trailed monotonously across a glittering snow field, unbroken, save where wind and tide had rifted the icy surface into cracks and leads of open water. As we cruised, three white whales darted under the protecting shelf of an ice floe, and polar bears, diving into the sheltering leads, sent up columns of spray that reflected the bright sunshine, frightened at the sight and noise of the weird monster that took to the air instead of the sea. As we approached latitude 83½° the snow-crowned peaks of Spitzbergen merged into the deepening blue of the southern sky, losing their identity; and all signs of life vanished. Intermittent light fogs hid the ice from our view, rolling beneath us like a great woollen ocean. Approaching 88° we had to rise from 1,800 feet to more than 3,000 in order to get over it.

Latitude 87° 44′—what memories! The motors were slowed down in commemoration of our sojourn there the year previous, although we were passing 50 miles to the eastward of the exact spot where we had been frozen in. It is difficult to separate days and nights in this latitude in the summer months, for the sun swings around the horizon at practically the same altitude during the entire 24 hours. As our Greenwich chronometer here told us that we had been out 16½ hours, the time was really 1.30 a. m. By May 12

the fog had completely cleared away, and there was no wind. The navigator who had been on his knees at one of the starboard windows since 1.10 with his sextant set on the height and declination that the sun should have at the pole, corresponding to the given date, suddenly announced, "Here we are!" as the sun's image started to cover his sextant bubble. We were over the North Pole!

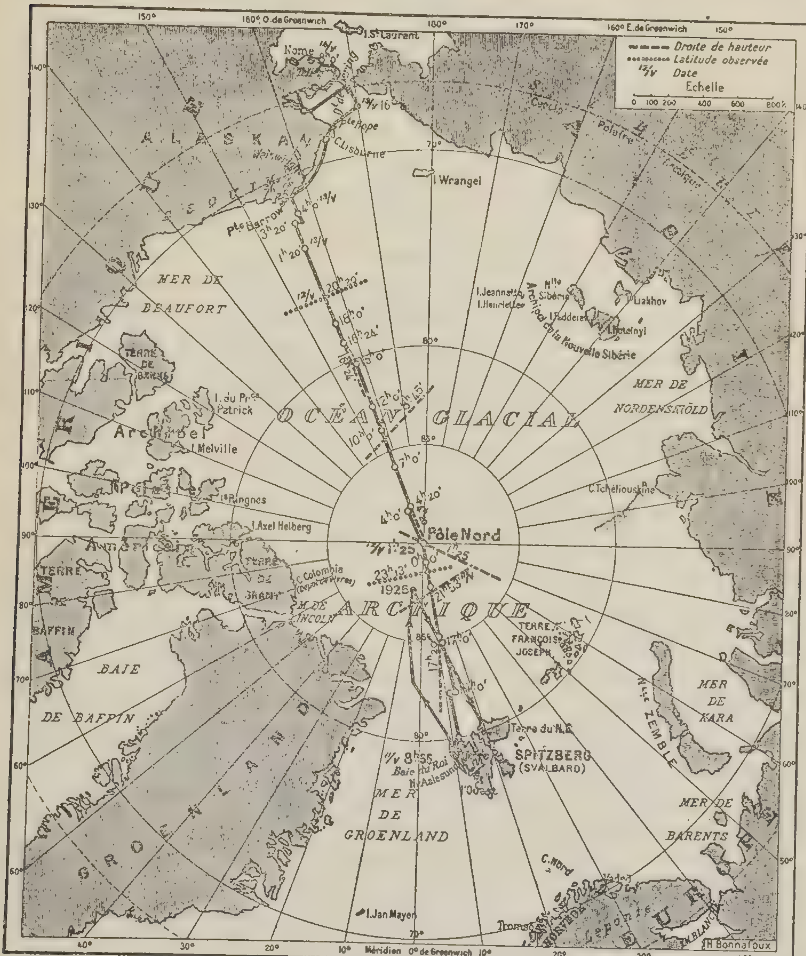


FIG. 1.—Route of the "*Norge*" across the Polar Sea, May 11–13, 1926. (3,393 miles). Also route of 1925 flight

With motors throttled and heads uncovered, we descended to within 300 feet of the ice and dropped the three flags. As we circled I hung over the side of the fuselage of our floating swing, lost in wonder at sight of the goal, the attainment of which had acted as the motive force to produce some of the most wonderful journeys, in the face of terrible conditions, in the history of our race; and as I recalled

the stories of the sufferings and hardships of these early travelers, they seemed like chapters taken from the Old Testament. "To seek, to strive, to find, and not to yield" had been their motto, and it was to them—"the trail breakers"—that Norway, America, and Italy paid silent tribute as they dropped their respective flags.

At 12.30 a. m., 40 nautical miles from the pole, a radiogram was handed me,.which read, "Passing into your forty-sixth birthday and another hemisphere, we send you our heartiest congratulations," and signed, "Your friends of Spitzbergen." My health was drunk in cold tea, for which I used Amundsen's South Pole mug marked "*Fram*, 11–12–1911." But as the time goes back one day in passing from one hemisphere to another "it looked," as I remarked in my diary, "as though I might get another celebration to-morrow."

"There is no more evanescent quality in an accomplished fact," says Conrad, "than its wonderfulness. Solicited incessantly by the considerations affecting its fears and desires, the human mind turns naturally away from the marvelous side of events." And it was in the most natural way possible that, after crossing the pole, we filled our mugs with meat balls immersed in a liquid of hot grease, from a large thermos cask, and, squatting down, anywhere out of the way of trampling feet, devoured the first and only hot meal of our entire voyage from Spitzbergen to Alaska.

Then with full speed ahead we settled down again to the monotony of routine, steering southward instead of north, with the sun compass settled for Point Barrow, Alaska, 1,500 miles away. Ahead lay the world's biggest unexplored area. What would it reveal—a lost continent, islands, or what? Could we cross safely so as to tell the world what we had seen? Although we were weary from lack of sleep, these questions animated every man aboard to a state of constant watchfulness and expectancy. Hour after hour passed, but there was only the same glittering surface, rifted by wind and tide into cracks and leads of open water, here, as before, crossing our route in a west-east direction. We reached the "Ice Pole" at 7 a. m., five and a half hours later. This "Ice Pole," so called because it is the center of the Arctic ice mass and therefore the most inaccessible spot in the Arctic regions, lies in latitude 86° N. and longitude 157° W. It had now been reached, but the 16 men that looked down upon the chaos of broken ice fields and pressure ridges of ice blocks, upturned as if giants had waged war with the polar ice, agreed that it would remain inaccessible except to aircraft. At latitude 86° we had covered one-half the distance between King's Bay and Point Barrow. Of the 7 tons of fuel the *Norge* carried, only about 2 tons had so far been consumed.

Here we picked up the first sign of life since leaving 83½° (almost 700 miles)—one lone polar-bear track. What a mockery to our

egotism! Yet there it was, plainly crossing a large ice floe. Only a polar bear, but then, something alive and seeking, like ourselves. At this sight the sense of utter solitude—the illusion of disembodiment—that had taken possession of me, as I seemed to float through the void like a lost soul, beyond the confines of a three-dimensional world, vanished, and in its place sprang hope. Just ahead, so it seemed, lay Alaska, the goal of our dreams.

But as we approached the Alaskan coast fears assailed us; for there we ran into the only storm during our entire voyage—fog, wind, and sleet—and for 31 hours we battled. In flying, as in life, it is not what we see, but what we can not see, that we fear. Each moment held not only something new, but something unpredictable. Ice coated the aerial wire and froze the windmill driver of our generator, which supplied the electrical energy to operate the transmitter and charge the storage batteries. All our efforts to establish communication with Alaska were of no avail. The last message from Alaska, before the wireless ceased to work, reported a cyclone that seemed to be stationary over Bering Sea. Ice crust formed in the bow of the ship, which was alarming, not only because it loaded her down, but also because it spoiled her trimming. We tried to counteract the effect by moving the fuel from the bow tanks and sending the crew aft. Needless to say, our greatest danger lay in the ice that was torn loose from the sides of the ship by the whirling propellers and thrown against the gas bags. An ice block of the most fantastic shape settled on the sun compass, which stopped the clockwork and put it out of action for the rest of the flight.

It was a surprise to find by observation at 4 a. m. on May 13 that we were in a nearly north-south position on a line striking the Alaskan coast and passing only 21 nautical miles west of Point Barrow, because it had been nearly 12 hours since the last longitude observation. At 6.45 a. m. land was sighted ahead on the port bow, and at 7.25, after a voyage lasting 48 hours, we reached the coast. Flat and snow covered, it was the most desolate looking coast line imaginable, but it was land and that was enough.

Passing over the coast line, the fog became denser and denser, obliging us to go lower and lower in order to be able to see far enough ahead so as not to run against obstacles. At last, abreast of Cape Beaufort, it became impossible to see any longer, and we rose through fog and cloud into bright sunshine. Heavy layers of fog drifted beneath us, and only now and then through openings in it could we glimpse the barren peaks of the Endicott Range, over which we were passing—far too little to enable us to make out our whereabouts. When we believed ourselves as far south as we should go we tried to drop underneath the fog and so find the way. We

had to nose down to an elevation of only 300 feet before we could see what lay beneath. Then we found that ice again. Where were we? At this moment our wireless, giving us a strange shock, picked up a strong signal, which we thought might be Nome, but we could not tell for certain, because it was a communication with another station and we could get no signature. But it gave us a position north of Diomede Island and enabled us to set a course for Cape Prince of Wales. Very soon we were over open water, which aroused our suspicions; we feared that we might be on the outside of Bering Strait, and with our course, heading straight for the Aleutian Islands. Coming out into sunshine again, we were obliged to take our observation from the top of the ship, as the sun at this latitude was so high that it was hidden by the envelope in whichever direction the ship pointed.

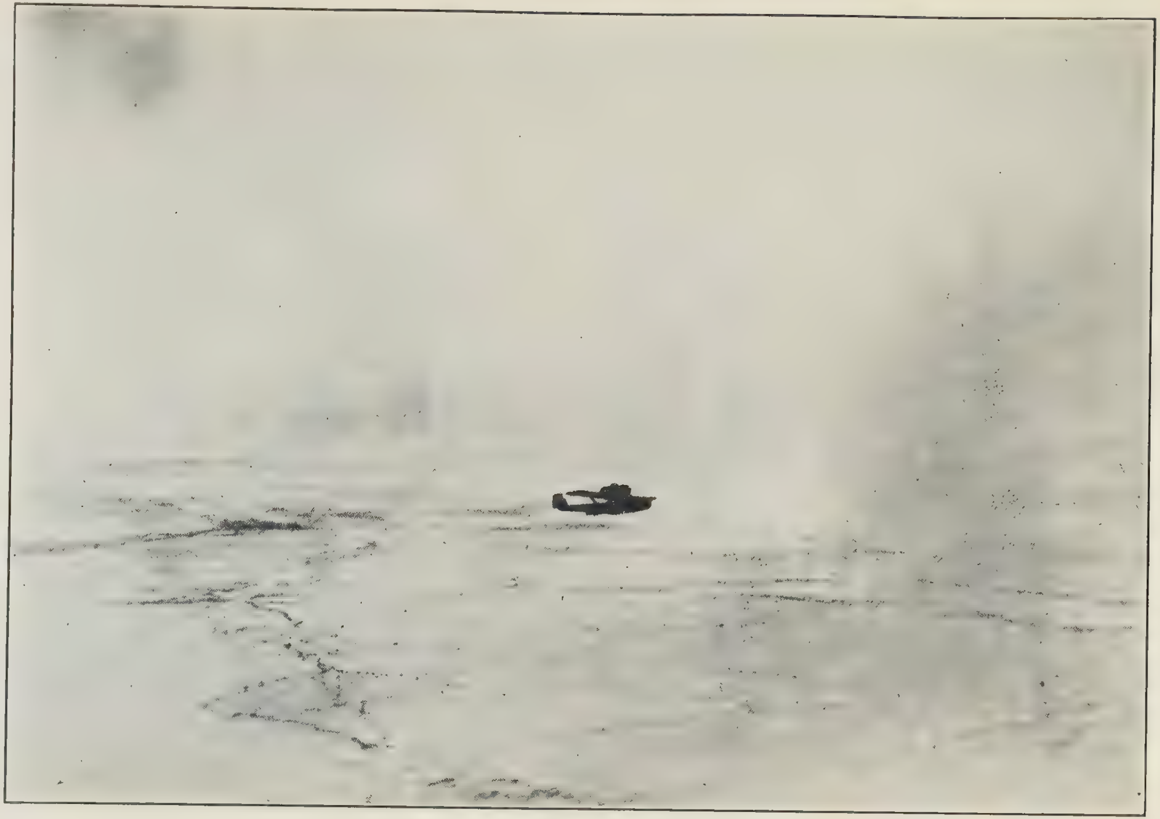
The observation gave our latitude as 67° 30′. We then went down through the clouds and found ourselves over land, having passed over the whole of Kotzebue Bay, driven by a northerly gale of more than 70 miles an hour. Heading west to get to the sea again, we heard the Nome wireless, which, together with the identification of the coast line, gave us our exact position. At 3.30 on the morning of May 14, we rounded Cape Prince of Wales, and, tired but happy, brought our airship, coated with a ton of ice, safely to rest at the little trading post of Teller, 91 miles northwest of Nome, after a journey of 3,393 miles, lasting 72 hours, across the Polar Sea from Europe to America.

This is the story of the flight itself—so far as it can be written. No words can describe the lure of that far-flung, strangely beautiful world of glittering white, lying beyond the rim of the Polar Sea over which we flew; no words can reveal the mystery, the melancholy, and the charm of that scene of our great adventure.

Now that the North Pole has been reached, and the Polar Sea itself crossed, it may appear to some that the ends for which such explorations were undertaken have been fully accomplished. Nothing could be further from the truth. Our flights open rather than close a chapter of discovery. In addition to the purely geographical problems awaiting solution in the unknown Arctic, a study of the physical conditions prevailing there is of vital importance. The circulation in our atmosphere is due mainly, as Nansen has said, to the heating of the air by solar radiation in the warmer regions and its cooling in the colder ones, especially in the polar area. To try to discover the laws governing the circulation of our atmopshere without a knowledge of the polar regions is comparable, therefore, Nansen argues, to the action of a man attempting to study the laws by which air circulates in the heating apparatus in a house, without knowing anything about the radiators that emit the heat. It is gen-

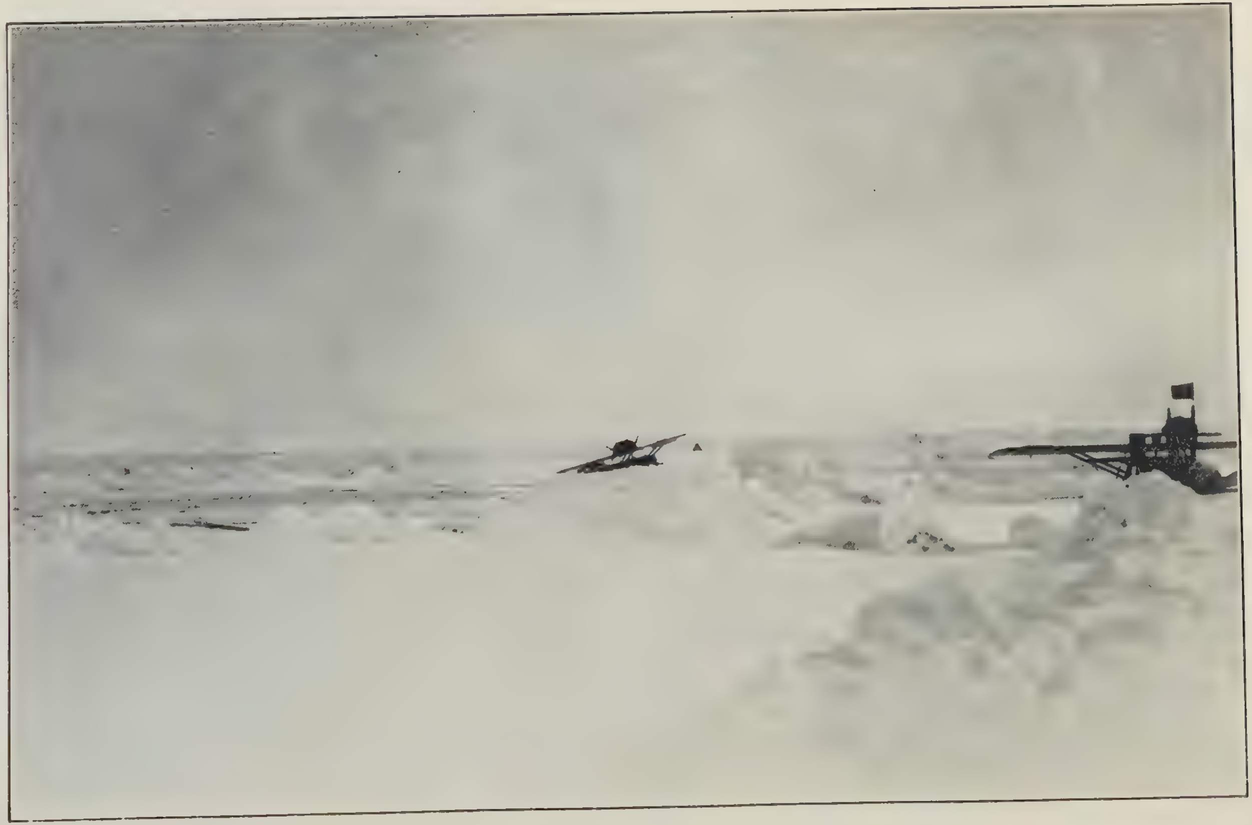
erally recognized that the meteorological conditions in the Arctic regions exercise a decisive influence upon weather conditions in our latitudes. It is likewise certain that magnetic observations, which make possible more accurate magnetic charts of the oceans, will result in a direct aid to shipping. These, then, are the most important of the unsolved problems still awaiting solution in the Arctic.

Happy is the explorer, seeking the truth for its own sake, who shall solve them.



JUST BEFORE LANDING AT LATITUDE 87° 44′ N.

(Amundsen-Ellsworth 1925 Expedition)



A "FORCED LANDING," 136 MILES FROM THE NORTH POLE

(Amundsen-Ellsworth 1925 Expedition)

TRYING TO GET "N 24" ONTO AN ICE FLOE BEFORE CLOSING OF THE BIG LEAD

(Amundsen-Ellsworth 1925 Expedition)

OUR ONLY IMPLEMENTS, 3 WOODEN SHOVELS, A 2-POUND POCKET SAFETY AX, AND AN ICE ANCHOR, WITH WHICH WE MOVED 300 TONS OF ICE

(Amundsen-Ellsworth 1925 Expedition)

WHERE FAITH ABIDES, THOUGH HOPE BE PUT TO FLIGHT

(Amundsen-Ellsworth 1925 Expedition)

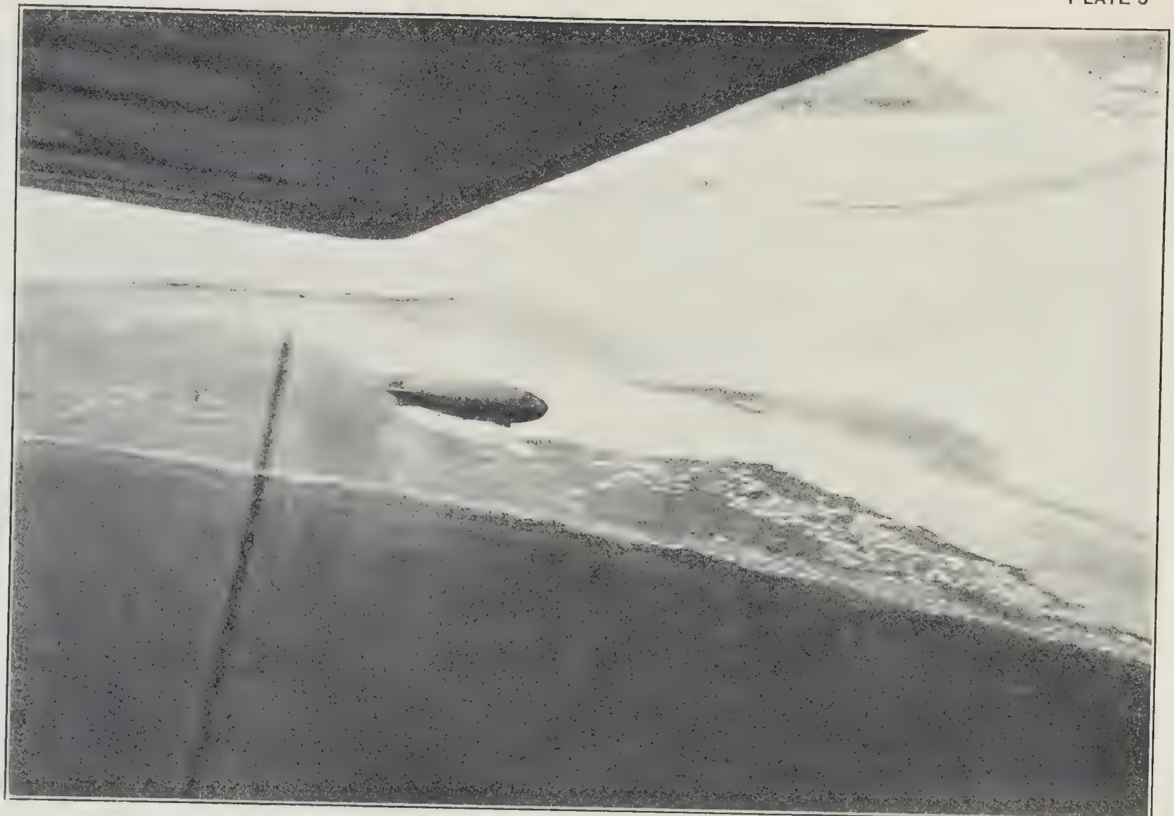
HOME AT LAST. "N 25" SAFE AT NORTH CAPE, SPITZBERGEN

(Amundsen-Ellsworth 1925 Expedition)

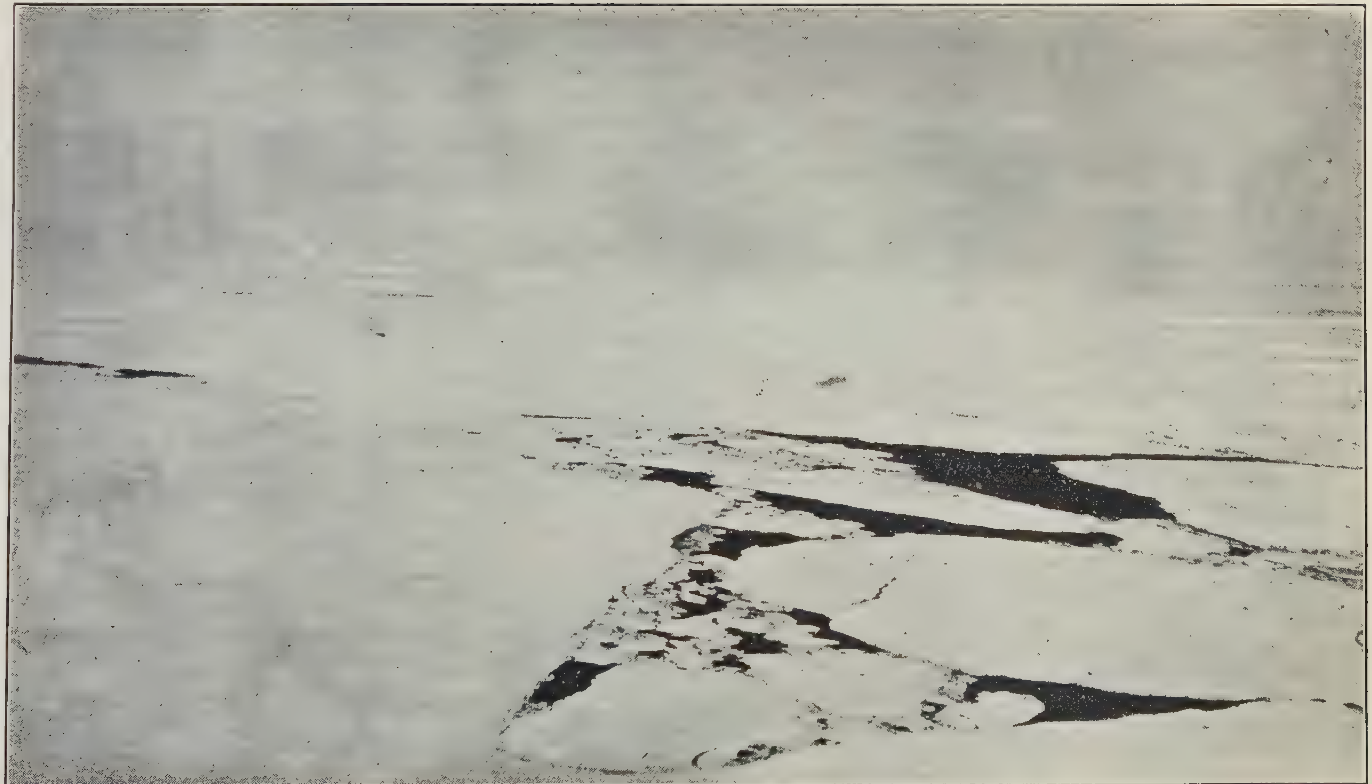
THE "NORGE" LEAVING HER HANGAR, KINGS BAY, SPITZBERGEN, 8.55 A. M., MAY 11, 1926

(Amundsen-Ellsworth 1926 Expedition)

THE "NORGE" DISAPPEARING INTO THE GLOOM OF THE NORTHERN SUN



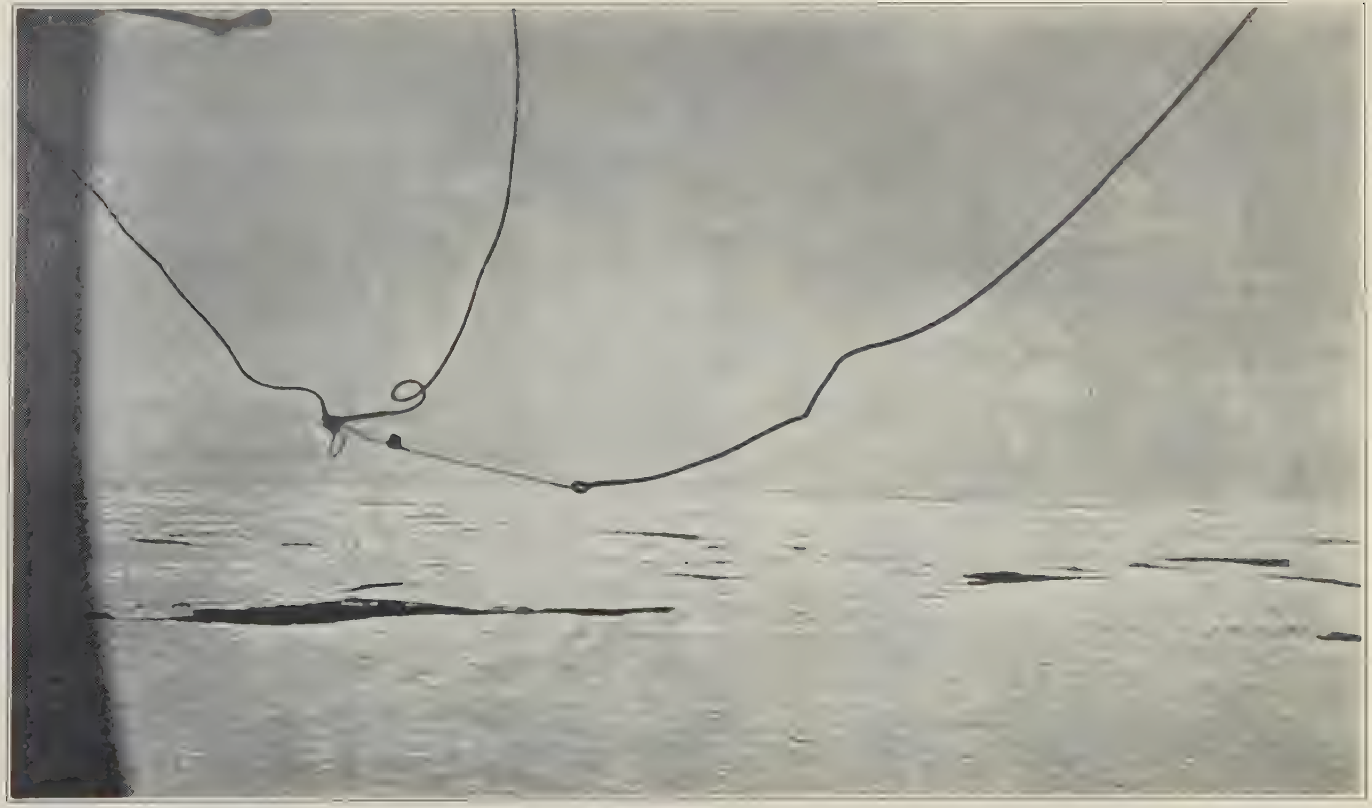
THE "NORGE" ON HER WAY, TAKEN FROM COMMANDER BYRD'S PLANE



THE NORTH POLE BEFORE THE DROPPING OF THE FLAGS

(Amundsen-Ellsworth 1926 Expedition)

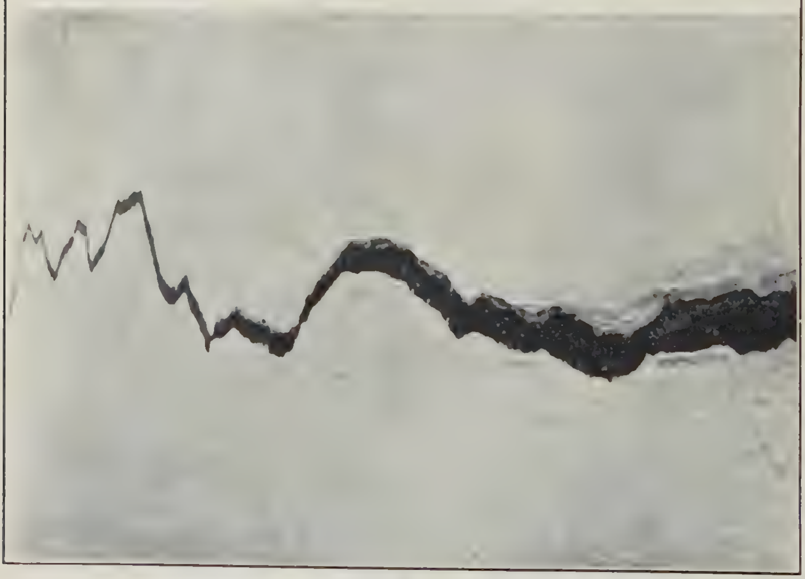
THE NORTH POLE



ALASKAN SIDE OF NORTH POLE

TAKING OBSERVATIONS FOR ATMOSPHERIC ELECTRICITY

1



2

CONDITIONS OF POLAR ICE AS SEEN FROM THE "NORGE"

1. Fringe of the "Polar-Pack." 2. A Great Lead from an altitude of 1,500 feet

THE "NORGE" COMING DOWN AT TELLER, ALASKA, AFTER A 3,393-MILE FLIGHT

BIRD BANDING IN AMERICA

By Frederick C. Lincoln

Associate Biologist, Bureau of Biological Survey, United States Department of Agriculture

[With 9 plates]

INTRODUCTION

The progress of our knowledge of birds necessarily involves a continued examination of concentrations of material and data brought together through the application of various methods, each of which furnishes definite contributions to the science of ornithology. Viewed in perspective, the splendid achievements of ornithologists during the past 75 years can not fail to impress the most critical reviewer with their magnitude and scope. This period witnessed the appearance of the modern standard works based upon original researches, which when passed in review are found to be as diversified as they are numerous. Explorations, critical reviews, monographs, and studies on migration and other phases of the life histories of birds have all received attention.

It is with the two last subjects that the present paper is chiefly concerned because of the new and pertinent facts that are being brought to light through an intensive application of the banding method.

The mysterious seasonal movements or migrations of birds have attracted the attention of students for hundreds of years, but it is only within comparatively recent times that adequate attention has been paid to the equally fascinating theme of their other life habits. With reference to migration, Dr. Glover M. Allen wrote in 1925 that:

> Mankind delights in a mystery of whatever sort, that thrill of something unknown to be discovered. For long years the migration of birds has stood as a delightful and mysterious riddle of Nature, but now bids fair to clear away and unfold more wonderful things than we dreamed of.

The monumental biographical works by Maj. Charles E. Bendire and Arthur C. Bent and the migration bulletins by Prof. Wells W. Cooke stand not alone as standards but they will also form the stimulus for further and more exhaustive investigations. In examining

the brilliant efforts of these scholars, replete though they are with copious information assembled for the first time, it will be observed that all are lacking in detailed accounts of the movements or actions of individual birds. Heretofore necessity has required that such studies should treat species en masse, for obviously no other course was possible. In this respect the anatomist, osteologist, and systematist, with their unchanging material ready before them, possess an enormous advantage over the student of the occult phases of the science. It is evident, however, that through the introduction of the banding or marking method systematic studies of these subjects may be carried on with a great degree of precision. It is, in fact, now possible to study birds as individuals, possessed of all the traits and mannerisms that are to be expected when the unit is separated from the group.

HISTORICAL

The widespread interest that has been developed in this subject during recent years has caused many to believe that it was merely a "new fad" that would soon wane as such. Bird banding, however, has already demonstrated its worth and claims a place with the shotgun, field glass, scalpel, and microscope, as a means of acquiring precise information relative to the birds around us. Furthermore, it is not an entirely new method even in America, for an examination of the literature reveals the fact that marking birds for a definite purpose was tried as long ago as 1803 when Audubon used silver wire to band a brood of phœbes (*Sayornis phœbe*) and was fortunate in obtaining two returns.

To Dr. Leon J. Cole must go the credit, however, for bringing the advantages of the method to the attention of American ornithologists, which he did in a short paper printed in the Third Report of the Michigan Academy of Sciences (1902). Following this came the work of Dr. Paul Bartsch, who in 1902 and 1903 banded black-crowned night herons (*Nycticorax n. naevius*), in the District of Columbia, with bands (Pl. 1. m.) that carried the address of the Smithsonian Institution (1904), from which he received several interesting return records. The records from these birds are apparently the first returns in modern times to be obtained from American birds, banded with the deliberate intent to learn something of their travels. About this time P. A. Taverner announced through the pages of The Auk (1904) that he proposed to take up this work and had had made aluminum bands inscribed with the legend "Notify The Auk, N. Y.' (Pl. 1, a.) Some of these bands were actually attached to birds, J. H. Fleming, of Toronto, Ontario, placing "Number 1" on a robin, on September 24, 1905. A few return records also were obtained, the

most noteworthy being the case of a flicker (*Colaptes a. luteus*) banded May 29, 1905, at Keota, Iowa, and killed the following Christmas Day at Many, La. Fragments of this bird are preserved in the Canadian National Museum at Ottawa, Ontario. Unfortunately these pioneer experiments did not receive their merited attention, and it was not until 1908 that the matter was again revived, this time by the New Haven (Conn.) Bird Club, which appointed a committee, under the able chairmanship of Doctor Cole, and issued to such of their membership as volunteered for the work both open and seamless bands stamped with the legend "Box Z, Yale Sta., New Haven, Conn." (Pl. 1, l.) A comparatively small number of these bands were used and within a year the legend was changed to the one used by Taverner ("Notify The Auk, New York"). (Pl. 1, b.) More than 5,000 of these bands were distributed, and about 1,000 were attached to birds as shown by Doctor Cole's report before the meeting of the American Ornithologists' Union in New York City in December, 1909, printed in The Auk for April, 1910. It also was during this period that the experiments of Dr. John B. Watson were carried on at the Tortugas Reservation in Florida (1909). In this work, paint was used to mark specimens of the noddy and sooty terns (*Anous stolidus* and *Sterna fuscata*) which were then shipped to Galveston, Tex., and to Cape Hatteras, N. C., air-line distances of between 800 and 900 miles, from which points the marked birds returned to their nests.

The results demonstrated so well the possibilities of such activities that on December 8, 1909, an organization known as The American Bird Banding Association was formed. The legend was again changed and the bands issued by the new association bore the inscription "Notify A. M. [=American Museum], N. Y." (Pl. 1, c, d.) Under the guidance of this organization, and particularly through the interest and zeal of its secretary, Howard H. Cleaves, bird-banding work was carried on until 1920, when it was taken over by the Bureau of Biological Survey of the United States Department of Agriculture.

Previous to this, Dr. Alexander Wetmore, while making investigations of the duck sickness at the Bear River marshes, Utah (1914 to 1916), banded about 1,000 ducks, using bands that carried the address of the Biological Survey. These were the first bands of this series. (Pl. 1, f.) The report by Doctor Wetmore (1923) of the 174 returns obtained amply demonstrated the possibilities of the method when applied to migratory waterfowl.

As originally practiced the banding of birds was used solely as a means of obtaining information pertaining to migration, and it is certain that this will always be a most valued phase of the subject.

It is, however, important to direct attention to one of the most interesting and important chapters in the annals of American bird-banding activities, written by S. Prentiss Baldwin, of Cleveland, Ohio, and which opened a new field for the study of life histories. In 1913, while engaged in a campaign to rid his premises of the English sparrows (*Passer domesticus*) he found that the elimination of these birds had the usual effect of attracting desirable native species to the vicinity. To reduce the sparrows, Mr. Baldwin used several traps of the type originated and recommended for this purpose by the Biological Survey. These traps, known as Government sparrow traps, capture the birds uninjured, leaving to the trapper their manner of disposition. Mr. Baldwin's first report of his banding work, which was presented to the American Ornithologist's Union at New York City on November 11, 1919, and later printed (1919), well describes how his investigations were started. He states, in part:

> * * * It was when I learned of the American Bird Banding Association that the traps acquired a new and much greater significance, for, as the house sparrows decreased, the traps became the resort of native birds. In the spring of 1914 I began placing bands, not only upon young birds in the nest, but upon many adults secured from the traps, and by 1915 it became evident that this could be done on a large scale, and with most interesting results in returned birds.

Mr. Baldwin's report came at a psychological time, as the results of Doctor Wetmore's work had caused Dr. E. W. Nelson, then Chief of the Biological Survey, to give serious consideration to the value of this form of study in connection with the administration of the migratory bird treaty act. In January of the following year (1920) the American Bird Banding Association dissolved its organization and turned over its records and effects to the Biological Survey. A short time later the writer was appointed to take charge of the work, now under governmental supervision.

PRESENT METHODS

The legend on the bands was again changed and those now in use carry on the outer surface, in addition to a serial number, the legend "Notify Biological Survey, Washington, D. C." (Pl. 1, e, g, h, i, j, k.) This complete legend can, of course, be impressed only on the larger bands, the smaller sizes having the words "Biological Survey," abbreviated to "Biol. Surv." or "Bi. Surv.," while the word "Notify" is omitted from the smallest sizes. The address, "Washington, D. C.," likewise is abbreviated to "Wash. D. C." and stamped upon the inner surface of the band. Any of these legends is, however, sufficiently complete to insure delivery of a letter, as the post-office officials have been fully advised of the work and have delivered promptly envel-

opes bearing such enigmatical addresses as: "Mr. Biol. Surv., 23171, Wash. D. C."; "Biol. Survey Co., Wash. D. C."; and "Boil Service, Wash. D. C." The word "boil" in the last example was due to a curious misprint in one lot of bands whereby the "o" and "i" were transposed. In addition to complicating matters for postal employees, this error caused many humorous comments from bird-banding cooperators, one of whom was fearful that the legend would be misunderstood as cooking instructions, since the bands plainly stated: "wash, boil, and serve."

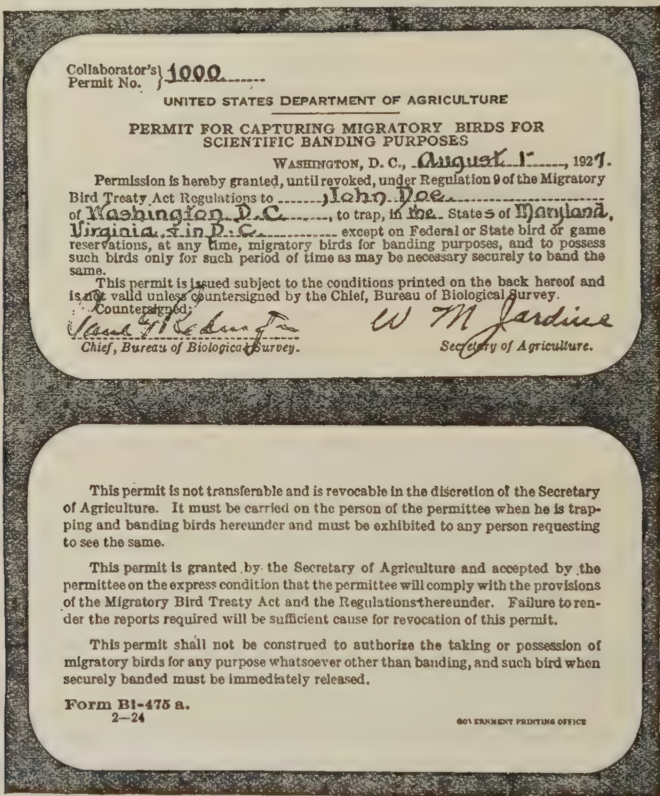
As the services of volunteer observers had been already successfully utilized by the bureau in other lines of work, it was decided to extend the system and to offer to the bird students of the United States and Canada this new form of research according to basic plans made by the Biological Survey. Since, however, nearly all American birds are protected by both Federal and State laws, it was apparent that prospective cooperators must comply with certain requirements. It was not proposed to have bird banding an excuse for indiscriminate nest hunting by school classes, Boy Scout troops, or other juvenile organizations, but to make it a method of study to be pursued only along lines that would make of unquestioned value the information obtained. Properly qualified persons are accordingly supplied with special Federal permits (fig. 1), permits that usually are supplemented by additional State authority. Through the cooperation of the Canadian National Parks Branch similar permits are granted to persons residing in Canada, and a foundation is laid for chains for bird-banding stations to cover the most populated parts of the continent north of the Rio Grande.

It will be at once apparent that American students of this means of research possess an enormous advantage over their coworkers in Europe. Not only are many species common to both the United States and to Canada, but there is also the added benefit of two large adjoining countries extending from the Tropics to the Arctic with a common language, while even in the Latin-American countries American influence renders reasonably certain a large number of return records.

At the present time over 1,200 persons have been supplied with bands, most of whom operate stations (pl. 2, fig. 1) where birds are systematically trapped and banded throughout the year. Most of these station operators are well-informed amateurs, it being obvious that the majority of the trained ornithologists are so occupied by their life work that they are unable to devote much time to bird banding. It is nevertheless a pleasure to record the fact that almost all workers in the science have given their full approval of the work, many of them are serving as regional advisers or councilors,

and some are operating trapping stations as actively as their time will permit.

The development of suitable traps and other equipment naturally received first attention and to certain ingenious individuals this phase of the subject will always hold a large measure of fascination. Inability with equipment at hand to capture certain species is a chal-



Collaborator's Permit No. } 1000

UNITED STATES DEPARTMENT OF AGRICULTURE

PERMIT FOR CAPTURING MIGRATORY BIRDS FOR SCIENTIFIC BANDING PURPOSES

WASHINGTON, D. C., August 1, 1927.

Permission is hereby granted, until revoked, under Regulation 9 of the Migratory Bird Treaty Act Regulations to John Doe of Washington D.C., to trap, in the States of Maryland, Virginia, & in D.C. except on Federal or State bird or game reservations, at any time, migratory birds for banding purposes, and to possess such birds only for such period of time as may be necessary securely to band the same.

This permit is issued subject to the conditions printed on the back hereof and is not valid unless countersigned by the Chief, Bureau of Biological Survey.

Countersigned:

Chief, Bureau of Biological Survey.

W M Jardine

Secretary of Agriculture.

This permit is not transferable and is revocable in the discretion of the Secretary of Agriculture. It must be carried on the person of the permittee when he is trapping and banding birds hereunder and must be exhibited to any person requesting to see the same.

This permit is granted by the Secretary of Agriculture and accepted by the permittee on the express condition that the permittee will comply with the provisions of the Migratory Bird Treaty Act and the Regulations thereunder. Failure to render the reports required will be sufficient cause for revocation of this permit.

This permit shall not be construed to authorize the taking or possession of migratory birds for any purpose whatsoever other than banding, and such bird when securely banded must be immediately released.

Form Bi-475 a.
2—24

GOVERNMENT PRINTING OFFICE

FIG. 1.—*Front and back of Federal bird-banding permit.* The specimen shown authorizes the banding of all kinds of migratory birds, but most cooperators hold permits permitting work only with nongame species

(Photograph from Biological Survey)

lenge that receives a ready response from cooperators with an inventive and mechanical turn of mind. Proper traps are moreover of great importance, and since thus far none but the hummingbirds have been excluded from the possible field it will be apparent that there is ample opportunity to work out traps of different types. As fast as these are perfected they are described and figured by the Biological Survey for the benefit of everyone interested. Usually it is found that the more simple and inexpensive the trap the greater

its efficiency. The records of banded birds are transmitted regularly to the bureau, where they are indexed and filed so as to be readily available for reference and study.

The foundation that has been laid through these activities at the present time (July 1, 1927) consists of about 300,000 banded birds, from which a total of about 15,000 returns have been received, not counting the thousands of repeat records which in themselves show many interesting facts. Explanation of the term " return " is necessary, because of its broad application in the records of banded birds. By return is meant the record of any banded bird recovered in a succeeding season, or the record of any bird terminated by its death. This means that the returns available consist of the records of birds banded at one point and recovered at another, retrapped at the point of banding during a different season (it being assumed that in the meantime migration has taken place), or of those that for one cause or another die at the point of banding without having left the vicinity. Ducks and other birds killed by hunters supply most of the data of the first type, the activities of station operators in retrapping the smaller nongame species furnish the records of the second class, while in the third are included those cases of adult birds accidentally or otherwise dying at the trapping stations within a short time of banding and of fledgling birds that die before reaching maturity.

It is obvious that data of the first two kinds have the most interesting features, but those of the third class, which are termed " short-time returns," also are being carefully assembled with the belief that through their study it will be possible to furnish valuable information on the mortality rates of certain species under known conditions. During the early phases of the work the activities of many persons were concerned solely with the banding of fledglings, which no doubt led to more or less organized nest hunting. For a time such work was tolerated as it was hoped that the interest of the participants would reach a point where they would operate the more productive trapping stations. Being well aware, however, of the attendant menace to bird life on account of unskillful handling of the birds and to human scent trails unwittingly laid from nest to nest for prowling house cats and other predators, the Biological Survey finally stopped all work of this character, except for the nests located upon the grounds of a trapping station where it is assumed that natural enemies of birds are kept under control. The banding of the young of colonial birds is authorized, however, when undertaken by operators who are thoroughly familiar with such special work.

Some birds acquire " the trap habit," that is, they will repeatedly return to a trap (pl. 2, fig. 2), occasionally being taken several

times during a single day. Records of these are called "repeats" and they, too, are carefully tabulated by the station operators. Through these opportunities to continually study an individual bird, noting its traits and personal habits, the progress of plumage colorings and growth, and many other items, important contributions are anticipated to our knowledge of life histories.

RESULTS OF COOPERATION--REGIONAL ASSOCIATIONS

In administering the bird-banding work the Biological Survey has offered to bird students a scientific method by which they may study birds and procure new and important information. The charm of intimate acquaintance with birds, brought about by the repeated handling of the same individuals, has had the effect of starting a wave of interest and enthusiasm unparalleled in the history of American ornithology. At the beginning, efforts were made to bring the matter to the attention of the public, but for the past four years nothing of this kind has been necessary, the number of new stations continuing to increase with remarkable rapidity.

In countries as large as the United States and Canada it is obviously difficult for any directing agency to be fully informed and to maintain proper contacts with the conditions that give rise to the local problems that appeal to the imagination of widely scattered station operators. For this reason and in order that their investigations might be better coordinated, both with the bureau and with each other, the field observers have been organized into regional associations.

The first of these was the New England (now the Northeastern) Bird Banding Association which was organized early in 1922 and assigned the territory of the New England States, Quebec, and the Maritime Provinces of Canada. Edward H. Forbush, State ornithologist of Massachusetts, was chosen as its first president. In October of the same year, at the Chicago meeting of the American Ornithologists' Union, a second organization, the Inland Bird Banding Association, was formed, with S. Prentiss Baldwin as president. The territory assigned to this organization was the vast area extending from the Allegheny Mountains to the Rocky Mountain States, including the Canadian Provinces of Saskatchewan, Manitoba, and Alberta. During the early part of 1923 the Atlantic coast area, exclusive of New England, but including New York and the Province of Ontario, was organized into the Eastern Bird Banding Association, with Dr. Arthur A. Allen, of Cornell University, as its first president. There remained only the territory represented by the Pacific coast and Rocky Mountain States and Provinces where a banding chapter of the Cooper Ornithological Club had been in

operation. Early in 1925, this group was definitely organized as the Western Bird Banding Association, with J. Eugene Law, of Altadena, Calif., as president.

It will be observed that each of these associations includes in its area at least one important migration highway, along which trapping stations may furnish data on certain specific problems. Such information will supply the stimulus for the continuation of the work, and in time will help solve other problems some of which can not now even be anticipated. To further such plans, the Eastern and Northeastern associations have both issued bulletins setting forth some of the results obtained by their members and other material of importance in the work. Similar information is made available by the Inland and Western associations through the pages of two well-established journals, The Wilson Bulletin and The Condor, as well as by special mimeographed circulars or news letters.

RESULTS

General.—Among the results of these studies there is one that while purely incidental nevertheless is important. This is the benefit to the birds. It seems scarcely necessary to state that bird-banding methods are neither cruel nor harmful, as the approved traps are merely cages of wire netting, while the weight of the bits of aluminium from which bands are made is utterly insignificant. Furthermore, a successful banding station necessarily must be the highest type of bird sanctuary. It is the object of the bander to attract more and more birds to his station in order that he may extend his studies, and to that end care is taken to keep it free from natural enemies. This coupled with abundant and varied food and water for bathing and drinking will ultimately make the trapping station a mecca for the birds of a wide area. A study of the conditions at certain stations has demonstrated that this is a fact. In other words, a banding station is a sanctuary or refuge that is made to yield information that serves for the increase of knowledge.

Occasionally, it is true, a bird is injured or even killed through an accident at the traps or while in the hands of the operators. Such cases are decidedly rare and do not average one to each thousand birds handled. One of the surprising features has been the rapidity with which new cooperators have mastered the technique of properly handling living birds. The small percentage of fatalities accordingly may be heavily discounted, for by no other method would it be possible to examine such a large number of individual birds without first transforming them into museum specimens.

Biological Survey bands have been placed on 437 species of North American birds, of which 231 have yielded at least one return

record. It will be recalled that with nongame species returns are secured mainly through retrapping by station operators, and thus far satisfactory methods have been devised for trapping only a relatively small number of species. Accordingly, the 206 species for which no returns have been received represent those banded largely or solely as nestlings. Such negative results are as expected, and it is axiomatic that marking such birds is not likely to be productive of important results (except over a very long period of time), if dependence for their recovery is placed solely upon the uncertain element of chance.

It is therefore apparent that the best prospects for early results lie in certain definite directions and that diversion of effort into minor channels is likely to diminish or delay them. With this in mind campaigns have been carried on through the regional associations which have resulted in the banding of large numbers of certain groups of birds such as gulls, terns, herons, swifts, swallows, and others. Invariably such efforts have yielded an increased percentage of data.

MIGRATION

It is safe to say that the underlying reason for all banding work has been the growing desire for more knowledge concerning the migrations of birds. Comprehensive reports on this subject can not be prepared by the individual worker, for it is only by the study and correlation of a mass of data from many different points that the subject can be satisfactorily treated. Dr. Witmer Stone (1908) has stated this condition with his usual precision. He says, in part:

> The meagerness of the data that it is possible for one individual to gather on bird migration, compared with the magnitude of the phenomenon, must be apparent to all, and yet we are constantly attempting all sorts of estimates—as to rapidity of flight, the relation of fluctuation of migration to temperature variation, etc.—based for the most part upon the records of individual observers.

These statements apply equally to the returns from banded birds which can be analyzed only by the worker who has access to all similar data and who is in a position to treat them with reference to other existing material. It is true, however, that we are being placed rapidly in possession of a large number of records for certain species from which it appears that the time is not far distant when it will be possible to prepare detailed reports on their migrations based largely upon banding data.

For reasons already stated it is impossible in a paper of this kind to do more than briefly summarize for a few species the information now available.

Caspian Tern.—The Caspian tern (*Sterna caspia*) has been banded in large numbers at colonies in Lake Michigan and to a lesser degree

at other points. (Pl. 3, fig. 1.) The returns received are sufficiently numerous to indicate the probability in the near future of an interesting study of the movements of this attractive bird. Banded individuals have been recovered south through the valley of the Mississippi River to its delta, on the Atlantic coast south of Chesapeake Bay to Key West, Fla., and in four cases from South America at the mouth of the Magdalena River, Colombia. One bird was retaken in central Oklahoma and (in the succeeding season) three others were found in Nova Scotia. A small colony of this species breeds in the Gulf of St. Lawrence, and it is assumed that the banded birds recaptured in Nova Scotia had moved north in company with members of this colony rather than with those of their parent colony from Lake Michigan.

Common tern.—Breeding colonies of the graceful common tern (*Sterna hirundo*) have been regularly visited by banders, the gross result of their efforts being the banding of more than 20,000 birds. The number of returns received is, however, disproportionate, due probably to the small size of the carriers and their efficient protection under the terms of the migratory bird treaty act.

The data obtained are nevertheless of much interest and are gradually building up a chain of important evidence pertaining to their migrations and wintering grounds. (Cf. Lincoln, 1927.) Outstanding among these returns is the case of a tern banded on the coast of Maine and four years later found recently dead at the mouth of the Niger River, British West Africa. To date, this is the only record of an American banded bird crossing the ocean, although several gulls (*Larus ridibundus* and *Rissa tridactyla*), banded in England and Germany, have been recovered in American waters. (Cf. Lincoln, 1925.)

Terns banded at colonies on the Atlantic coast have been reported south to the mouth of the Chumpan River, in Mexico (pl. 3, fig. 2), Porto Rico, French West Indies, the island of Trinidad, and the coast of Venezuela. As one of the narrow parts of the Atlantic Ocean is between the coasts of Brazil and western Africa, and in view of the other data at hand, it seems reasonable to presume that occasionally birds wintering on the northeastern coast of South America strike boldly out to sea and cross to the African coast.

Common terns banded at colonies in the Great Lakes also have been retaken south to southern Mexico, but they also show a wide dispersal throughout the southeastern United States. (Pl. 4.)

Herring gull.—The herring gull (*Larus argentatus*) has a wide distribution in North America, and the large colonies have proved attractive fields for banding activities, over 6,000 having been banded.

Because of their large size, these birds, although protected by Federal law, have yielded many returns.

As a family, gulls are more or less nomadic, and true migratory flights appear to be the exception rather than the rule. This is borne out by the banding returns, as in some seasons the birds have remained during the winter in northern latitudes, even moving still farther north. Birds marked as fledglings in northern Lake Michigan have been detected during the same season in the region of the Gulf of St. Lawrence. On the other hand, long flights are not infrequent, specimens from the Great Lakes colonies having been reported south to Florida, Louisiana, and southern Texas, while two proceeded south as far as the State of Vera Cruz, Mexico.

White pelican.—Although banded in comparatively small numbers, returns from white pelicans (*Pelecanus erythrorhynchos*) have partially indicated the routes taken by these birds from some of their breeding grounds. One banded in southern Saskatchewan was recaptured five days later in South Dakota. The large colony of these birds that regularly breed at Yellowstone Lake, in the Yellowstone National Park, Wyo., was studied in 1922, and about 100 young birds were banded. Several returns were received showing that after leaving the breeding grounds the pelicans crossed a low pass northwest of the lake and then pursued a line of flight almost due south through the Great Basin. One was killed at Otatitlan, State of Vera Cruz, on the east side of the tableland of Mexico. (Cf. Ward, 1924.)

Mallard.—Of all species that have been banded, the mallard (*Anas platyrhynchas*) has yielded the largest percentage of returns, because of the many reports from sportsmen. In the United States this duck is most abundant in the Mississippi Valley, and it is here that the majority were banded, about 4,000 having been trapped in the State of Illinois by the writer alone. (Pl. 5, fig. 1.) Others have been banded on the Atlantic, Pacific, and Gulf coasts and at several points in Canada. About 1,800 returns have been received. These show the line of flight with much accuracy between points in Mackenzie, Alberta, Manitoba, and Saskatchewan in the north, to the coast of Louisiana and Texas in the south. As would be expected, the flight extends over a rather wide front through the Dakotas, Nebraska, Kansas, and Oklahoma, although the majority of the records have been received from points close to the main stream. Upon reaching the region of the Gulf of Mexico some of these birds evidently work westward, as indicated by the returns from the Texan coast. Birds banded in central Illinois and Missouri also have been taken as far west as Colorado, Wyoming, Montana, and California.

Mallards banded in southwestern Ontario in the autumn no doubt accompany the large flocks of black ducks, flying southwest to the

Ohio and Mississippi Valleys. They have been reported in succeeding breeding seasons north and west to central Alberta.

Black duck.—Among migratory waterfowl the black duck (*Anas rubripes*) is next in numerical order of banding returns. While this species has been banded in small numbers at points in the Mississippi Valley and on the northeast Atlantic coast, the majority of the data have come from birds banded in southwestern Ontario, where for several years a highly productive station has been operated. Altogether more than 1,000 returns have been received for this species.

From an examination of this material it is evident that the principal fall flight from southern Ontario is to the southwest, the ducks reaching the United States by way of the western end of Lake Erie. From this point the flight continues to the valley of the Ohio River, and extending in that general direction brings the migrating birds to the Mississippi River. There is also another route, seemingly less important, as the number of returns each season is proportionately smaller. This extends southeast to the Atlantic coast, which apparently is reached about the latitude of Delaware Bay and Chesapeake Bay. Between the banding station and the coast there are but few returns along this route, and as a range of mountains must necessarily be crossed the birds probably travel at a relatively high altitude and without intermediate stops.

The summer records from these birds are mostly from points in Quebec and Ontario north to James Bay. Only occasionally does the species extend far to the westward, although a few banded black ducks have been taken as far west as Alberta. (Cf. Lincoln, 1922.)

The scattered returns from birds banded in the Mississippi Valley supplement those from Ontario, as they are from points northeast to Michigan, Ontario, and Hudson Bay. One only from this region has been recovered from the Atlantic coast.

Blue-winged teal.—The blue-winged teal (*Querquedula discors*) has been banded in fairly large numbers and the returns received indicate that interesting results will be obtained. This little duck is the last to arrive in the spring and the first to go south in the fall, the bulk of the individuals regularly passing south of the United States, their winter range extending well into South America.

Most of the banded teals were marked in Ontario, South Carolina, Louisiana, Kansas, and Missouri. The records from the South Carolina birds help to confirm belief in the existence of the route across from the Atlantic coast to the Mississippi Valley, several having been taken on the crossing. From the Mississippi Valley the records extend northward to the Provinces of central Canada.

The birds banded in Kansas are of special interest as they were all young hatched at the point of banding. Upon migrating they moved south through Texas to the State of Campeche in southern Mexico, and the next year they traveled north through Nebraska at least to Minnesota. Blue-winged teals banded in Ontario have seemingly followed the general routes of the black duck, although the returns are more equally dispersed along the Atlantic coast and the Mississippi Valley. One bird that probably followed the coastal route was taken on the island of Trinidad, British West Indies, about 75 days after banding, while another was killed during the following autumn near Burlingame, Calif.

Pintail.—The pintail (*Dafila acuta*), which as a species is almost cosmopolitan, probably breeds farther north than any other of the *Anatinæ.* Banding of these birds has been done mostly in the Mississippi Valley States and in California. It accordingly is not surprising that the general route of migration of the former group appears to be similar to that of the mallard, except that the pintails no doubt push farther north. Several records have been received from northern Manitoba, Alberta, and the Northwest Territory.

Seven birds banded in Kansas and in the Mississippi Valley have been reported from California. Pintails are notoriously high flyers, and as a matter of fact, in view of the many occurrences of this and other species of ducks on lakes and streams at relatively high altitudes, it may be considered doubtful if the mountains anywhere offer an impassible barrier to such strong flying birds, although they probably have a certain directing influence in much the same manner as does a large and important river. The records from the birds banded by Doctor Wetmore (1923) at Great Salt Lake, Utah, have already shown the existence of a flyway from that point to the great valleys of California. It is, however, curious that all returns from pintails banded in California are from points on the Pacific coast, north to Alaska, none having been reported from eastern points. (Pl. 5, fig. 2.)

Cackling goose.—Among the returns received from banded Canada geese (*Branta canadensis*) are between 40 and 50 for the smallest North American race, the cackling goose (*Branta c. minima*), that are particularly noteworthy. These birds were banded during the summer of 1924 in the vicinity of Hooper Bay, northwestern Alaska. The returns, received during the following shooting season, show well the line of flight south along the coast of British Columbia by way of the Queen Charlotte Islands to the mouth of the Columbia River. At this point the route turns inland for a short distance and then resumes a southward direction, reaching its terminus at winter quarters around the shores of Tule Lake in Oregon and California and in

the Sacramento Valley of California. The data indicate an extremely circumscribed range during winter, a fact that should be of much concern to naturalists and sportsmen interested in the perpetuation of this goose as a game bird. (Cf. Lincoln, 1926.)

Herons.—Among the herons, returns are available for several species, but (excepting the black-crowned night heron) there is not a sufficient accumulation to warrant any statements concerning their migration. Great blue herons (*Ardea herodias*) banded in Minnesota have been recovered south in Iowa, Missouri, and Texas, the State of Oaxaca, Mexico, and at Gatun Lake, Panama.

Snowy egrets (*Egretta candidissima*) banded at Great Salt Lake, Utah, have been found along the Rio Grande in Texas and south to Sinaloa, in western Mexico, while two reddish egrets (*Dichrománassa rufescens*), banded on the coast of Texas, were recovered in the Mexican States of Campeche and Oaxaca.

The black-crowned night heron (*Nycticorax nycticorax*) has been banded in large numbers, particularly at a colony on Cape Cod, Mass. In common with some other members of this family, these birds have the curious habit of a northward migration after the breeding season, which is well shown by the returns received. (Pl. 6, fig. 1.) Records are numerous through the New England States and in southeastern Canada, the most northerly being one taken at Lake St. John, Quebec, while they also extend westward to western New York and Michigan. With the approach of winter the birds are driven south and the returns show the route through Pennsylvania, Virginia, North Carolina, and Georgia to Florida, Louisiana, Cuba, Haiti, and Jamaica. (Cf. May, 1926.) Night herons banded in central Canada have been retaken south through the Mississippi Valley to Texas, Florida, and Vera Cruz, Mexico.

Mourning dove.—The status of the mourning dove (*Zenaidura macroura*) as a migratory bird has been challenged, so that unusual interest attaches to the records from banded birds. These data include cases of birds retaken at the point of banding on both the summer and winter ranges and also those banded as breeding birds and retaken on migration or after arrival in their winter habitat. Doves banded in Illinois have been captured chiefly in Louisiana, Florida, and Georgia, although one wandered west to east-central Texas. There also are a few other records of recoveries in Texas from birds banded in Indiana, Ohio, and Missouri, but, to judge from the bulk of the returns reported for these birds, the principal wintering grounds are in Georgia.

Birds of prey.—The migration of the birds of prey (pl. 6, fig. 2) have long excited much interest and while these birds are not easily obtained for banding and records will accumulate slowly, nevertheless important results may be confidently expected.

Thus far, banded marsh hawks (*Circus hudsonius*) have yielded the largest number of interesting returns. Birds banded north as far as Ontario have been recovered in North Carolina and Florida; and birds banded in central Illinois have been reported from Texas and also from Michigan. A Cooper's hawk (*Accipiter cooperi*) banded at Willoughby, Ohio, was killed during the winter of the same year at Sublime, Tex.; and a ferruginous rough-leg (*Archibuteo ferrugineus*) banded at Red Deer River, Alberta, was taken about three months later, at Kimball, Nebr. Two young duck hawks (*Falco p. anatum*), banded on the same day at Russell, Mass., were both killed during the following spring, one at Canton, Pa., and the other at Nokesville, Va. Another bird of this species, banded at Kings Point, Yukon, in July, 1924, was taken at Duchesne, Utah, during the following February, about 2,300 miles from the point of banding.

Some interesting light has been shed on the movements of some of the owls (pl. 7, fig. 1), although much more data are needed.

The screech owl (*Otus asio*) seems to be sedentary throughout its range. Returns from birds banded at points in New England, through the plains, and Rocky Mountain areas to the Pacific coast, all are in the same general vicinity of banding. On the other hand, banded barn owls (*Tyto pratincola*) have yielded a few returns showing that these birds can and do perform lengthy journeys. One banded at Oradell, N. J., in summer, was taken the following January, at Savannah, Ga.; another, also banded in New Jersey, was recovered at Wilmington, N. C.; while a third, banded at Nashville, Tenn., was killed about six months later, at Opp, Ala.

An interesting record also is at hand for a snowy owl (*Nyctea nyctea*) banded early in July, 1924, at Hooper Bay, Alaska, and killed in November of the following year, on King Island, off the coast in Bering Sea.

Chimney swift.—Among the smaller birds the migrations of the chimney swift (*Chætura pelagica*) (pl. 7, fig. 2) holds an unfailing interest, principally because of the lack of definite information regarding its winter home. The innumerable host of these birds that gathers in the Gulf States, disappears suddenly and completely in the fall, causing many of the credulous to still maintain that they spend the winter on hibernation beneath the waters of the Gulf of Mexico.

Although banding was not considered as a means of tracing them beyond the borders of the United States, it was obvious that a species available in such large numbers should receive attention. During the last few years more than 11,000 have been captured for banding by means of specially constructed traps (pl. 8) that literally take

every bird that enters a chimney to roost for the night. Most of these have been taken in the vicinity of Thomasville, Ga., and Tallahassee, Fla., and through the continued operation of the traps, twice each year, many return records are being obtained. Several swifts have been recaptured at the banding points in both spring and fall, showing that the route for the individual birds is apparently the same for both migrations. Birds also have been taken from a chimney in one town, and a week or ten days later recaptured at another 15 to 30 miles distant. Swifts banded at these points have been recovered north through Pennsylvania and New York to New Brunswick and Nova Scotia.

Crows and jays.—The migration flights of the *Corvidæ* are not well understood, due principally to the fact that the different species are frequently observed continuously throughout the year in many localities. Their journeys are, however, more or less regular, banding returns showing some interesting and lengthy flights. Blue jays (*Cyanocitta cristata*) banded in Illinois and Iowa (pl. 9, fig. 1) have been retaken in Missouri and Arkansas; and a magpie (*Pica p. hudsonia*), banded near Laramie, Wyo., in May, was killed near Rosita, Colo., during the following January. The crow (*Corvus brachyrhynchos*) appears to make the longest flights of any member of this family. Birds banded in Illinois have been retaken in Wisconsin and Michigan; one banded in Saskatchewan in June was killed in Oklahoma in the succeeding January, while one banded in Oklahoma in January was recovered three months later in Minnesota.

Blackbirds.—In this family there are two species for which return data are rapidly accumulating, due to the large numbers that are being marked. Because of their local economic importance, it is expected that information from recovered birds will be useful in the formulation of adequate control measures.

The total number of banded red-winged blackbirds (*Agelaius phœniceus*) is only slightly more than 3,000, but, nevertheless, many interesting returns have been obtained. Many gaps remain to be filled in, but the data at hand indicate the route followed by these birds, from Connecticut through New Jersey and Maryland; from Michigan, Minnesota, and Wisconsin south through Illinois and Tennessee to Alabama and Texas.

The grackles (*Quiscalus quiscula*) come so readily into yards and gardens that it is not surprising that more than 7,000 have been marked by station operators. From these the returns exceed 350. They can, of course, be only briefly mentioned in this paper, but it is apparent that eventually these data will be sufficiently numerous to form the basis of an independent contribution. Birds banded in the extreme eastern part of the range (Ontario, New York, Massa-

chusetts, and Pennsylvania) apparently adhere to the coastal route, as the majority of the returns come from points in Maryland, Virginia, and the Carolinas; while those marked in the Central States (Michigan, Wisconsin, Ohio, Indiana, Illinois, and Iowa) follow the great Mississippi River flyway through Tennessee, Arkansas, and Missouri to winter quarters in Mississippi, Louisiana, and Texas. Records showing the return flight in spring are similar but contain also a few instances of erratic wandering, which is best shown by one banded at Auburn, Ala., in March and retaken two months later at Pawnee City, Nebr.

Sparrows and finches.—The members of the family *Fringillidæ* easily constitute the majority of the birds banded at small bird-trapping stations. Responding readily to many kinds of bait and traps, every station reports them regularly. Naturally, when traps are operated year after year many birds are recaptured, some supplying an unbroken series of records for several years. Such data are highly important but obviously must be analyzed in connection with information from other sources. With this in mind it is desirable here to mention only a few of the more striking cases, returns that give evidence of the length of the flights made by these diminutive travelers.

Purple finches (*Carpodacus purpureus*) are favorites at many stations and among the great numbers of "station returns," there also are some recoveries from distant points. Birds banded at Sault Ste. Marie, Mich., have been found later in Tennessee and Arkansas; one banded at Pasadena, Calif., in March was recovered in June, at Porter, Wash.; and one from Wellesley, Mass., was found dead at Rockingham, N. C. The most remarkable flights for this species are shown by two birds, one banded at Norwalk, Conn., and retaken at Haynesville, La.; and the other banded at Peterboro, N. H., and recovered five months later at Thornton, Tex.

A few miscellaneous returns for other species in this group will show the character of the information that is being accumulated. A white-crowned sparrow (*Zonotrichia leucophrys*) banded at Indianapolis, Ind., was retaken in the following year at Doucet, Quebec; and another of this species marked at Seattle, Wash., was caught again at Watsonville, Calif. A white-throated sparrow (*Zonotrichia albicolis*) banded at Ithaca, N. Y., in April was found the following January at Cumming, Ga. A chipping sparrow (*Spizella passerina*) was banded at Westfield, Mass., and later recovered from Pamplico, S. C. A remarkable return for a Junco (*Junco hyemalis*) is the case of one banded at Crystal Bay, Minn., and retrapped at Demarest, N. J. Another Junco from Cleveland, Ohio, was retaken at Alexis, N. C., while a third was banded in

central Saskatchewan and found a few months later at Forest City, Iowa. Even the song sparrow (*Melospiza melodia*), which as a species is frequently noted throughout the year in one locality, can and does make extensive flights. The longest flight reported for one of these birds, is the case of one marked at South Waterford, Me., and taken four months later at Jacksonville, Ga. There are several other records for this species from birds banded in New England and recovered on the South Atlantic coast, while one banded at Danvers, Mass., was recaptured between two and three months later at Weymouth, Nova Scotia.

Robin.—It seems desirable to end the migration portion of this survey with a brief résumé of the flights of the well-known robin (*Planesticus migratorius*), of which more than 11,000 have been marked with aluminum bands, yielding a net result of more than 500 returns. The records of special interest come from birds banded in the Central States—Michigan, Minnesota, Wisconsin, Ohio, Indiana, and Illinois—which in moving south have spread out fanwise to Georgia, Kentucky, Tennessee, Mississippi, Alabama, Arkansas, Louisiana, and Texas. It is curious that so many returns for robins banded in Michigan, Ohio, and Indiana should come from Georgia, and it is interesting to speculate upon the course that they followed. Eventually the chain of evidence will be complete and it will be possible to state with precision the flyways utilized by this and other species. The longest flight thus far reported for a small nongame, perching bird is for a robin banded in midsummer at Crystal Bay, Minn., and taken a year and a half later at Pachuca, Hidalgo, Mexico.

LIFE HISTORY

While migration is admittedly a most important part of the life histories of birds, it has been found necessary for the purpose of analyzing data to treat it as a separate subject, and the term "life history" is therefore restricted to the study of the habits of a species through a series of individuals, in which bird banding has its chief interest for the station operator. Such investigations, from the viewpoint of the increase of knowledge, are of great importance, as they will bring to light many facts that heretofore have been unknown or, at best, merely suspected. In the final analysis, bird banding depends for its results upon quantity production, so it follows naturally that those species that yield most easily to the present technique of the method are those concerning which the first contributions will be made. By the daily operation of their traps (pl. 9, fig. 2) station operators are acquiring a great fund of new information pertaining to individual birds.

Every student who has observed local birds throughout the year is aware that the distribution of the individuals, of even the so-called resident species, changes with the season. This is no doubt due to changes in food supply, environment, and probably to physical impulses. In short, the ecological conditions vary enough to force the individual birds to vary their habitat, while it is also true that the area under observation may receive a few additional individuals of the same species that may be migrants or merely wanderers from an adjoining area. Under the ordinary methods of study it is difficult or impossible for the observer to be sure that the same individuals are constantly under observation, in contrast to which the station operator, daily retrapping many of the local birds, can truthfully say that he knows the individual birds in the area contiguous to his station. He is accordingly able to record with accuracy the acts that each performs.

The accumulation of material of this character necessarily will be very slow, for each observation must be checked and rechecked at different points. In this respect two or more operators working together in the same general vicinity have many advantages that will expedite the development of their investigations. It also will be recalled that the majority of present-day bird banders are novices, and as such it is proper that they use every care to present only data that will bear the closest scrutiny. They are, however, learning rapidly, and the number of independent studies being undertaken is constantly increasing. It seems safe at this time to predict that these ornithologists, now in the making, will devote more and more attention to such subjects as the development of plumage in relation to the life cycle of the bird; body temperatures under different conditions and their relationship to weight and physical conditions; the effect of external parasites upon plumage and general health; heredity and the dominance of certain characters; and other matters that in the past have received but passing notice. Within the past year a circular letter addressed by the Biological Survey to all bird-banding cooperators, requesting information of the subjects that were of particular interest to them, brought in 187 replies, showing that at some stations three or four distinct studies were in progress, those above named having preference.

Every effort is made to counsel station operators against the error of premature publication, in the belief that it is desirable to carry a study to its logical conclusion from the standpoint of available facilities before making the results known in print. Accordingly, but little has appeared from the banding stations on these subjects, and it is not possible at this time to do more than refer briefly to work in progress.

Foremost among these investigations is the study of the house wren (*Troglodytes œdon*) that is being conducted by S. Prentiss Baldwin at his research laboratory near Cleveland, Ohio. This work, which has been carried on for five or six years, promises to be one of the most detailed studies ever made for a passerine bird. For the past two or three years Mr. Baldwin (1921) and his associates have published but little of the results that have been obtained, although the work has been greatly expanded and has involved the employment of special assistants and much delicate apparatus. The genealogies of the house wrens breeding in the vicinity have been worked out with much care, while many data have been collected relative to periods of courtship, nest building, intervals between deposition of eggs, incubation periods, activities of parents during incubation (Baldwin, 1927), length of time spent in nests by young birds, second broods, and other items.

Among the *Fringillidœ* are four or five species that merit special attention because of their quick response to the trapping methods generally employed. The song sparrow (*Melospiza melodia*) easily ranks first as shown by the fact that more than 13,000 have been banded. This species is plentiful in the regions where trapping stations are concentrated, thus facilitating cooperative work to determine the extent of local ranges and migratory movements. Through these activities it is learned that there is an interchange of individuals, the winter birds moving on and their places being taken by arrivals from other sections. Song sparrows repeat regularly, so a close check may be maintained on their actions. A statistical analysis of such data obtained at one station has been published by Rudyerd Boulton and John T. Nichols (1925).

Studies of the development of plumages constitute a phase of the work that has a direct appeal to many operators. The first of these to be undertaken was by Michael J. Magee, who has already published (1924) a preliminary report of his observations on the plumage of the purple finch (*Carpodacus p. purpureus*). In his study of this species, more than 4,000 individuals have been banded which have yielded 250 returns at his own station, together with thousands of repeat records. His notes definitely trace the plumage from the juvenile stage through the changes up to adults 3 or 4 years old. It has been found that most, if not all, males of this species do not acquire the full crimson plumage until they are 2 years old, and even then it is not the richly colored plumage of the old male, which is apparently not acquired by birds less than 4 years old.

Pacific coast stations are making similar investigations concerning the plumage of the house finch (*Carpodacus m. frontalis*) and the Gambel sparrow (*Zonotrichia l. gambeli*), while others in Eastern

States are conducting studies on the Junco (*Junco hyemalis*) and goldfinch (*Astragalinus tristis*).

The diseases affecting wild birds and their possible relation to species under domestication are occasionally of such importance as to call for work by trained specialists, all of whom deplore the lack of data on the subject which causes the loss of valuable time for preliminary work. Admittedly, this is a subject too difficult for the average bird bander, but it is a pleasure to record that among the active cooperators of the Biological Survey there are several physicians who are applying their skill and general knowledge to studies of avian ailments. Among the more common of these affections is one which causes injuries and deformities to the feet and legs of birds. It has been detected on chipping sparrows, Juncos, bronzed grackles, red-winged blackbirds, and others. Some success has already been attained in treating the disease, while experimentation is still in progress.

The study of avian parasitology is abundantly aided through the activities of trapping stations. This is particularly true regarding the "bird flies" *Hippoboscidae*, insects that are difficult to collect as they will almost immediately desert their host upon its death. At a few banding stations special equipment has been installed for the capture of these insects and many have been obtained, some being taken from hosts not previously recorded. The importance of such work will be apparent when it is remembered that biting flies are frequently responsible for the transmission of disease from an animal that acts only as a carrier to one that may be violently susceptible. Other parasitic insects also may be involved, and arrangements are being perfected whereby the services of specialists will be made available for the examination of infected birds obtained from banding stations.

Baldwin (1922), Whittle (1923), and L. B. Fletcher (1924) have contributed interesting information concerning what is termed "the group habit." From the evidence obtained it appears that certain groups or small flocks of such species as tree sparrows, juncos, and white-throated sparrows retain their identity throughout a season and even maintain basically the same organization in successive seasons. As Mr. Whittle says (loc. cit.), "There is * * * some evidence that there exists something like orderly procedure in such migrating bodies and that there may be definite groups having perhaps family or neighborhood relations which constitute migratory units." This theory, if satisfactorily demonstrated and followed to its ultimate conclusion, might throw important light upon the evolution of geographic races.

Longevity of birds in a state of nature and the mortality rate of young birds are subjects that frequently are given much discussion.

John T. Nichols, of the American Museum of Natural History (1927), gives good expression to a theory governing the normal span of life of birds, which he states as "a high death rate prior to gaining full adult strength and vigor, then comparative safety until the decline with age begins, then almost immediate elimination." As Mr. Nichols states, this implies "a fairly definite normal age limit at or slightly beyond the point where physical decline sets in," and "accumulating data * * * on longevity from banded birds would approach the limit, but rarely exceed it." Since, however, prompt elimination almost certainly takes place when the physical decline is begun, it would appear that a sufficient quantity of long-time records for banded birds of any species should furnish a reasonable average for the normal life of that species. Obviously, the time element in this problem is such as to make it a continuing project subject to frequent revision upon the acquisition of additional data.

At the present time the oldest American banded bird that has been reported was a pintail (*Dafila a. tzitzihoa*) banded by Dr. Alexander Wetmore on September 16, 1914, at the mouth of Bear River, Utah, and which was killed near Brawley, Calif., either on October 16 or 17, 1926. This bird was adult when banded and so was at least 1 and probably 2 or 3 years old, thus making its age at death at least 13 years. Among smaller species there are available several records for individuals 4, 5, and 6 years old, and a few that were at least 7, 8, and 9, when last reported.

Such investigations can be multiplied almost endlessly, so that the application of the banding method permits both professional and amateur students of birds to render important contributions to science through studies conducted with living birds.

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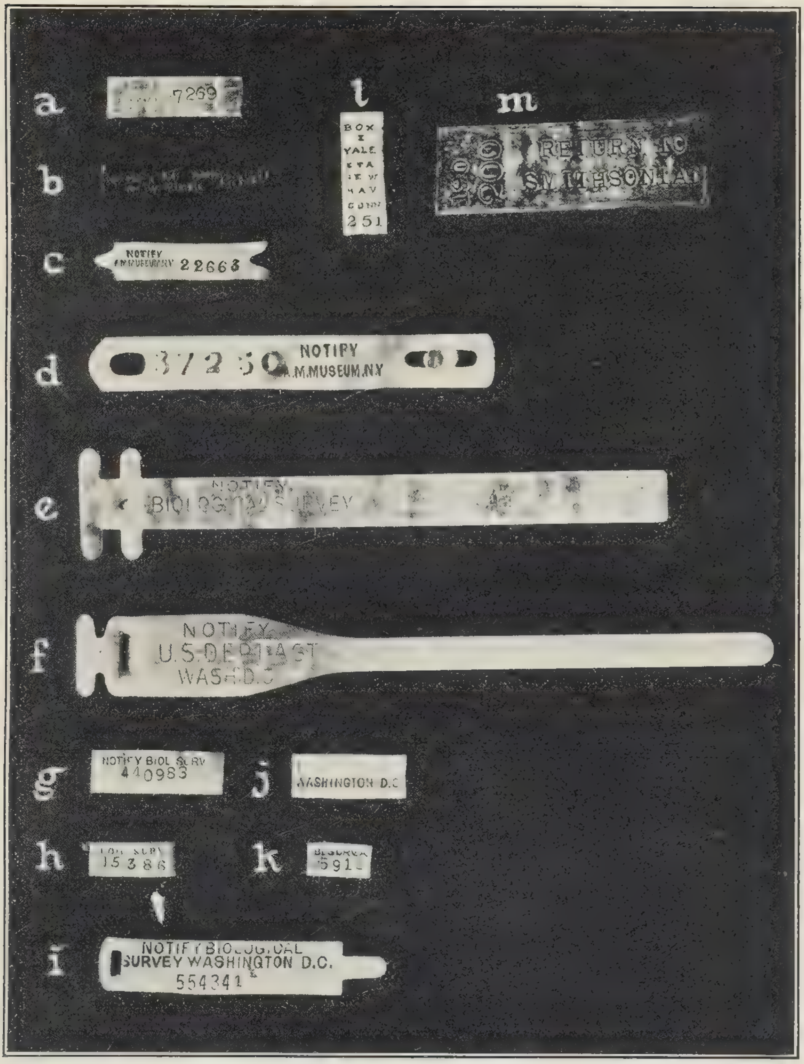


BANDS USED IN MARKING NORTH AMERICAN BIRDS

Lettering from top to bottom they are: *a*, split-ring band, made and issued by P. A. Taverner; *l*, seamless band, first issue of the New Haven Bird Club; *b*, flat strip band, second issue of the New Haven Bird Club, the one shown being made of thin brass; *c* and *d*, ring bands of the American Bird Banding Association; *e* and *f*, flat strip bands, the first used by the Biological Survey; *g*, *h*, *i*, *j*, and *k*, the present split-ring bands of the Biological Survey; *g* and *j* show the outer and inner surfaces; *h* shows the misprint on one lot whereby "Biol. Surv." was made to read "Boil. Surv."; *k* shows the smallest band with legend abbreviated to "Bi. Surv." followed by the series letter, and the number restricted to five figures; *i* shows a lock band with complete legend, the type used on waterfowl and other large birds; *m*, bands used by Dr. Paul Bartsch, bearing name of the Smithsonian Institution. (Photograph from Biological Survey)

1.—AN EFFECTIVE BACKYARD TRAPPING STATION

Several traps are in use, including a protected feeding station trap on elevated platform, a collapsible drop trap on the ground, and small window feeding shelf traps. (Photograph by Charles L. Whittle)

2.—PURPLE FINCHES AND JUNCOS FEEDING UNDER AND AROUND A DROP TRAP

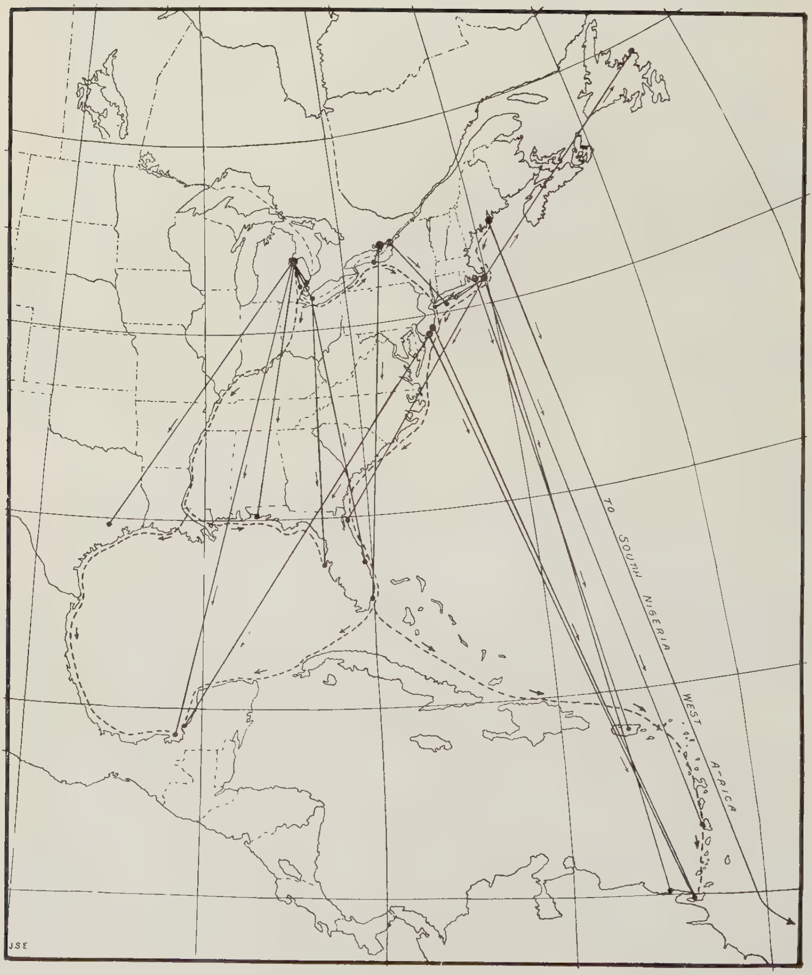
Most of these birds are banded so the records of recapture here would be "repeats." (Photograph by Charles L. Whittle)

1.—MORE THAN 700 FLEDGLING CASPIAN TERNS, IMPOUNDED IN A CORRAL FOR BANDING, AT A COLONY IN NORTHERN LAKE MICHIGAN

(Photograph from Biological Survey)

2.—COMMON TERN BANDED ON THE COAST OF NEW JERSEY AND RECOVERED NEAR CARMEN, SOUTHERN MEXICO

The specimen in a mummified condition is preserved in a glass jar, as "No. 767" of the collection of "El Caos," Carmen, Campeche. (Photograph by Jose Jesus Cervera)



FLIGHTS MADE BY BANDED COMMON TERNS

The straight lines connect points of banding and recovery while the broken lines indicate theoretical routes that probably were followed. (Photograph from Biological Survey)

1.—THE AUTHOR IN A LARGE DUCK TRAP, SUCCESSFULLY OPERATED IN THE MARSHES OF THE ILLINOIS RIVER

Note the captured mallards gathered in the rear end of the trap. (Photograph from Biological Survey)

2.—DUCK TRAPPING STATION AT LAKE MERRITT, OAKLAND, CALIF.

Large numbers of pintails have been banded at this station. (Photograph by E. W. Ehmann)

1.—BANDED YOUNG BLACK-CROWNED NIGHT HERON

Returns from these birds have demonstrated many interesting features in connection with their migratory flights. (Photograph by W. B. Purdy)

2.—A BROOD OF BANDED SPARROW HAWKS

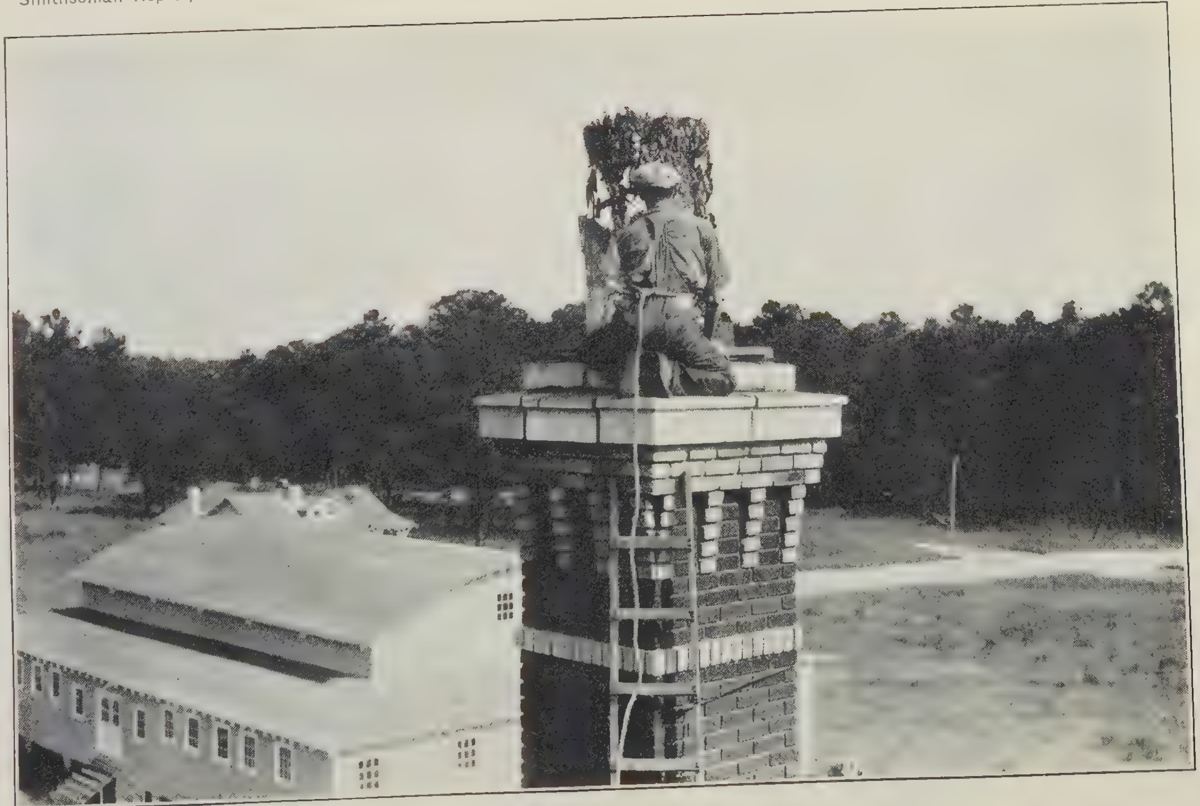
Several birds of this species, banded in Massachusetts, have been retaken in Maryland and Virginia. (Photograph by H. P. Ijams)

1.—BANDING A SNOWY OWL

Several of these Arctic visitors were marked with bands during the invasion of 1926–27. (Photograph by Frank J. Vejtasa)

2.—SIX BANDED CHIMNEY SWIFTS

Many species of birds will lie on their backs for variable p.eriods of time in seeming ignorance of their liberty. (Photograph by H. L Stoddard)

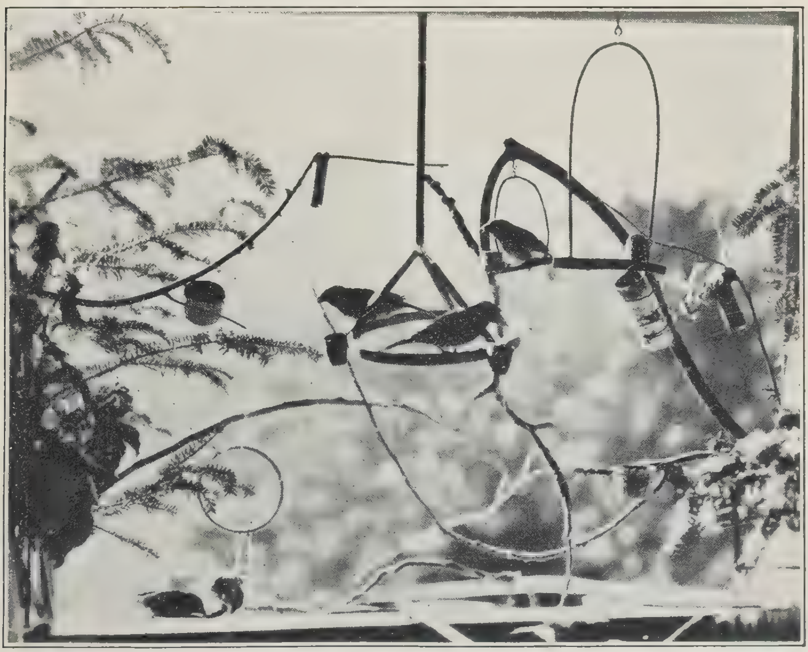


TRAPPING CHIMNEY SWIFTS FOR BANDING

By means of specially constructed traps, thousands of these birds have been taken from chimneys where they gather before and after the nesting season. (Photograph by H. L. Stoddard)

1.—FIVE BLUE JAYS AND TWO BRONZED GRACKLES FEEDING AT A DROP TRAP

Both of these species are captured in large numbers, and important information is being obtained from banded individuals. (Photograph by E. C. Hoffman)



2.—A PRODUCTIVE WINDOW TRAPPING STATION

This station, operated at an upper window of a summer hotel, has been exceptionally successful. The birds are mostly purple finches with a ruby-throated humming bird at the extreme right. (Photograph by Eleanora S. Morgan)

GOLDEN TROUT (SALMO ROOSEVELTI EVERMANN) OF
VOLCANO CREEK, CALIF.

THE DISTRIBUTION OF FRESH-WATER FISHES [1]

By DAVID STARR JORDAN

[With 2 plates]

The phrase "Distribution of fishes" (as with distribution of other organisms) involves two separate but closely related problems: First, the actual facts in regard to the presence in the various waters of certain species which constitute the fish fauna; second, the problem for each species, of how did it get there. For every kind of fish had its origin somewhere, and for the most part not in any stream it now inhabits. For each different fish fauna is very old in the temperate zones, mostly dating back to the last glacial period, and to the readjustment of conditions which followed the expansion and the recession of the ice.

The science of zoogeography deals with both series of problems, the actual location of different species on the surface of the earth, and the laws or relations of cause and effect by which their location is determined.

In physical geography we may prepare maps of the earth or of any part of it, these bringing to prominence the physical features of its surface. Such maps show here a sea, there a plateau, here a mountain chain, there a desert, a prairie, a peninsula, or an island. In political geography the maps show the physical features of the earth as related to the people who inhabit them and the states or powers which receive or claim their allegiance. In zoogeography the realms of the earth are considered in relation to the species or tribes of animals which inhabit them. Thus series of maps could be drawn representing those parts of North America in which catfishes or trout or sunfishes are found in the streams. In like manner the distribution of any particular fish as the muskallonge or the yellow perch could be shown on the map. The details of such a map are very instructive, and their consideration at once raises a series of questions as to the cause behind each fact. In science it must be supposed that no fact is arbitrary or meaningless. The word "discontinuous" has only a relative meaning, if any, in biology. In the case of fishes the details of the method of diffusion of species afford matters of deep interest.

[1] This article is based in large part on earlier ones of the author on the same subject, in Science Sketches, 1887 and 1896, and one in Fishes, 1925.

The dispersion of animals may be described as a matter of space and time, the movement being continuous but modified by barriers and other conditions of environment. The tendency of recent studies in zoogeography has been to consider the facts of present distribution as the result of conditions in the past, thus correlating our present knowledge with the past relations of land and water as shown through paleontology. Dr. A. E. Ortmann well observes that "Any division of the earth's surface into zoogeographical regions which starts exclusively from the present distribution of animals without considering its origin must always be unsatisfactory." We must therefore consider the coast lines and barriers of Tertiary and earlier times as well as those of to-day to understand the present distribution of fishes.

The general laws governing the distribution of all animals are reducible to three very simple propositions.

Each species of animal is found in every part of the earth having conditions suitable for its maintenance, unless—

(*a*) Its individuals have been unable to reach this region through barriers of some sort; or,

(*b*) Having reached it, the species is unable to maintain itself, through lack of capacity for adaptation, through severity of competition with other forms, or through destructive conditions of environment; or else,

(*c*) Having entered and maintained itself, it has become so altered in the process of adaptation by selection as to become a species distinct from the original type.

The absence from the Japanese fauna of most European or American species comes under the first head. The pike has never reached the Japanese lakes, though the shade of the lotus leaf in many clear ponds would suit its habits exactly. The grunt (*Haemulon*) and porgies (*Calamus*) of our West Indian waters have failed to cross the ocean and therefore have no descendants in Europe or Asia.

Of species under (*b*), those who have crossed the seas and not found lodgment, we have, in the nature of things, no record. Of the existence of multitudes of estrays we have abundant evidence. In the Gulf Stream off Cape Cod are taken every year many young fishes belonging to species at home in the Bahamas and which find no permanent place in the New England fauna. In like fashion, young fishes from the Tropics drift northward in the Kuro-Shiwo (Black Current) to the coasts of Japan, but never finding a permanent breeding place and never joining the ranks of the Japanese fishes. But to this there have been, and will be, occasional exceptions. Now and then one among thousands finds permanent lodgment, and by such means a species from another region will be

added to the fauna. The rest disappear and leave no trace. A knowledge of these currents and their influence is essential to any detailed study of the dispersion of fishes.

The occurrence of the young of many shore fishes of the Hawaiian Islands as drifting plankton at a considerable distance from the shores was first noted by Dr. Charles H. Gilbert. Each island is, in a sense, a "sphere of influence," affecting the fauna of neighboring regions.

In the third class, that of species changed in the process of adaptation, most insular forms belong. As a matter of fact, at some time or another almost every species must be in this category, for isolation is a source of the most potent elements in the initiation and intensification of the minor differences which separate related species. This is a factor never to be overlooked in the study of the origin of species. It is not the preservation of the most useful features, but of those which actually existed in the ancestral individuals, which distinguish such species. Natural selection must include not only the process of the survival of the fittest, but also the results of the survival of the existing. This means the preservation through heredity of the traits not of the species alone, but those of the actual individuals who have been the first in the line of descent in a new environment. In hosts of cases the persistence of characters rests not on any particular usefulness or fitness, but on the fact that individuals possessing these characters have, at one time or another, invaded a certain area and populated it, being subjected thereby to new selections and new adaptations. The principle of utility explains survivals among competing structures. It rarely accounts for qualities associated with geographical distribution.

The extinction of species may be noted here in connection with their extension of range. Several writers, following Dr. Herbert Osborn, have recognized five different types of elimination, each more or less hypothetical. 1. That extinction which comes from modification or progressive evolution, a relegation to the past as the result of a transmutation into more advanced forms. 2. Extinction from changes of physical environment which outrun the powers of adaptation. 3. The extinction which results from competition. 4. The extinction from extreme specialization and limitation to special conditions. 5. Extinction as a result of exhaustion.

As an illustration of No. 1, we may take almost any species which has a cognate species on the further side of some barrier or in the Tertiary seas. Thus the trout of the Twin Lakes in Colorado has acquired its present characters in the place of those brought into

the lake by its actual ancestors. No. 2 is illustrated by the disappearance of East Indian types (*Zanclus*, *Platax*, *Toxotes*, etc.) from Italy at the end of the Eocene, perhaps for climatic reasons. Extinction through competition is shown in the gradual disappearance of the Sacramento perch (*Archoplites interruptus*) after the invasion of the river by catfish and carp. From extreme specialization certain forms have disappeared, but no certain case of this kind has been pointed out among fishes, unless this be the cause of the disappearance of the Devonian mailed *Ostracophores* and *Arthrodires*, or of various types modified by orthogenesis. It is not likely that any group of fishes has ever perished through exhaustion of the stock of vigor. Exhaustion is an individual not a collective matter.

We are now learning in some detail the methods of transmutation of species, the adjustment in nature of new forms, and I do not need to discuss the matter here. Suffice it to say that natural selection enforces not separation but adaptation, in which all forms which maintain themselves must share, and no variations, however favorable, can crowd out the original stock, which must have the advantages of long-continued heredity, and at the beginning, at least, the likelihood of being smothered by crossbreeding. I do not believe that any new and permanent species was ever established in nature by any form of mutation or discontinuous variation or that any variation really discontinuous ever occurs. Neither is there any serious evidence that new species are ever formed in nature by any hybridism, Mendelian, or otherwise. The various phases of Mendelism concern heredity, but not to any great extent the methods of species forming. A species, as I understand it, is a definable group of animals or plants produced in the natural divergence of life, which has run the gauntlet of time and which has endured. The problem of the origin of species relates to forms which have lasted.

That most genera of sea fishes of Miocene times and their species have passed away is evident to students of paleontology. That the living faunas are in general made up of the same elements as in Miocene times is also evident, these elements belonging mostly to the same families, though rarely to the same genera. That shore fishes become extinct with time is evident, though the causes for their disappearance are largely hypothetical. The chief of them is the alteration of external conditions, climate sometimes, sometimes the appearance of new friends or new enemies, changing the conditions of life by placing a new or different stress on the breeding of the species. Other causes are often suggested and some may have a degree of value. Among these are the modifications due to progressive evolution, whatever that may be; but we may well look with doubt on alleged

changes not due in part at least to external causes. The forces behind orthogenesis may belong here, but both fact and cause of these phenomena are still obscure. Another suggestion is that forms become "extinct through exhaustion." This again is purely hypothetical, as we know no "exhausted species," although many are very rare, perhaps becoming more so. Fresh-water fishes sometimes disappear through their inability to meet competition with new arrivals. Authors have recognized different types of elimination of species, these being theoretical chiefly and not certainly known to occur in nature.

The limits of distribution of individual species or genera must be found in some sort of barrier, past or present. The chief barriers which limit marine fishes are the presence of land, the presence of great oceans, the differences of temperature arising from differences in latitude, the nature of the sea bottom, and the direction of the oceanic currents. That which is a barrier to one species may be an agent in distribution to another. The common shore fishes would perish in deep waters almost as surely as on land, while the open Pacific is a broad highway to the albacore or the swordfish.

Again, that which is a barrier to rapid distribution may become an agent in the slow extension of the range of a species. The great Continent of Asia is undoubtedly one of the greatest barriers to the wide movement of species of fish, yet its long shore line enables species to creep, as it were, from bay to bay, or from rock to rock, till, in many cases, the same species is found in the Red Sea and in the tide pools or sand reaches of Japan. In the North Pacific the presence of a range of half-submerged volcanoes, known as the Aleutian and Kurile Islands, has greatly aided the slow movement of the fishes of the tide pools and the kelp. To a school of mackerel or of flying fishes these rough islands with their narrow channels might form an insuperable barrier.

It has long been recognized that the matter of temperature is the central fact in all problems of geographical distribution. Few species in any group freely cross the frost line, and, except as borne by oceanic currents, not many extend their range far into waters colder than those in which the species is distinctively at home. Knowing the average temperature of the water in a given region, we know in general the types of fishes which must inhabit it. It is the similarity in temperature and physical conditions which chiefly explains the resemblance of the Japanese fauna and that of the Mediterranean or the Antilles. This fact alone must explain the resemblance of the Arctic and Antarctic faunæ, there being in no case a barrier in the sea that may not some time be crossed. Like forms lodge in like places. Similarity of conditions produces convergencies of type but never homology.

We may consider the fresh-water fishes alone for the purpose of the present paper; for them we may divide the land areas into districts and zones not differing fundamentally from those marked out for mammals and birds. The river basin, bounded by its shores and with the sea at its mouth, shows many resemblances, from the point of view of fish dispersion, to an island considered as the home of a mammal. It is evident that with fishes the differences in latitude outweigh those of continental areas, and a primary division into Old World and New World would not be tenable.

The chief areas of distribution of fresh-water fishes we may indicate as follows:

With Doctor Günther [2] we may recognize first the northern zone, characterized familiarly by the presence of the sturgeon, salmon, trout, whitefish, pike, lamprey, stickleback, and other types of which the genera and occasionally the species are identical in Europe, Siberia, Canada, Alaska, and most of the northern United States, Japan, and China. This is subject to cross division into two great districts—the first Europe-Asiatic, the second North American. These two agree very closely to the northward, but diverge widely to the southward, developing a variety of specialized genera and species, and both of them passing finally by degrees into the equatorial zone.

Still another line of division is made by the Ural Mountains in the Old World and by the Rocky Mountains in the New World. In both cases the eastern region is much richer in genera and species, as well as in autochthonous forms, than the western. The reason for this lies in the vastly greater extent of the river basins of China and the eastern United States as compared with those of western Europe or of the California region.

Minor divisions are those which separate the Great Lakes region from the streams tributary to the Gulf of Mexico; and in Asia, those which separate China from tributaries of the Caspian, the Black, and the Mediterranean Seas.

The equatorial zone is roughly indicated by the Tropics of Cancer and Capricorn. Its essential feature is that of the constantly high temperature, and the peculiarities of its divisions are caused by barriers of sea or mountains.

In the Tropics the best line of separation into two divisions lies in the presence or absence of the great family of dace or minnows (Cyprinidæ), to which nearly half of the species of fresh-water fishes of the world belong. The entire group, now spread everywhere except in the Arctic, Antarctic, South America, Australia, and

[2] "Introduction to the Study of Fishes."

the islands of the Pacific, seems to have had its origin in India, from which region its genera have radiated in every direction.

The cyprinoid division of the equatorial zone forms two districts, the Indian and the African. The acyprinoid division includes South America, south of Mexico, and all the islands of the tropical Pacific lying to the east of "Wallace's Line." This line separates Borneo from Celebes and Bali from Lompoe, and marks in the Pacific the western limit of cyprinoid fishes, as well as that of monkeys and other important groups of land animals. This line, recognized as very important in the distribution of land animals, coincides in general with the ocean current between Celebes and Papua, which is one of the sources of the Kuro-Shiwo.

In Australia, New Zealand, Hawaii, and Polynesia generally, the fresh-water fishes are derived from marine types by modification of one sort or another. In no case, so far as I know, in any island to the eastward of Borneo, is found any species derived from fresh-water families of either the eastern or the western continent. Of course, minor subdivisions in these districts are formed by the contour lines of river basins. The fishes of the Nile differ from those of the Niger or the Congo, or of the streams of Madagascar or Cape Colony, but in all these regions the essential character of the fish fauna remains the same.

The third great region, the southern zone, or sub-Antarctic, is scantily supplied with fresh-water fishes, and the few it possesses are chiefly derived from modifications of the marine fauna of the equatorial zone to the north. Three districts are recognized—Tasmania, New Zealand, and Patagonia.

The degree of survival among the marine fishes, from the Miocene period on, is fairly well tested in various deposits, but of fresh-water forms we have scanty record. The numbers of the species of fishes preserved in the strata of dried-up ponds and similar locations is very small, and the most that we can say of them is that they belong to families still extant, and most of them to genera now extinct but closely related to living forms. The hundreds of thousands, or millions, of years since the Miocene have given time for incidents which change the stress in the lives of animals enough to produce a change in generic characters on the part of most of them. Among those animals which have the widest range of environment, these changes occur most rapidly; hence fishes of the Miocene differ more from their living types than most mollusks do.

Among marine fishes the changes can be most clearly shown because the amount of material is vastly greater. The phenomena of geminate or twin species occur in all groups. With geographical separation, as with geological separation, we find arising forms which

differ in a few but definite respects, these differences being greater with greater distance or greater time since the original physical separation. This fact is the basis of Jordan's Law of Geminate Species, so termed by Dr. Joel A. Allen, the distinguished ornithologist, and accepted by all careful students of taxonomy in relation to geographical distribution. This " law " as laid down in 1908 reads as follows:

> Given any species in any region, the nearest related species is not likely to be found in the same region nor in a remote region, but in a neighboring district separated from the first by a barrier of some sort or at least by a belt of country, the breadth of which gives the effect of a barrier.

When I was a boy and went fishing in the brooks of western New York, I noticed that the different streams did not always have the same kinds of fishes in them. Two streams in particular in Wyoming County, not far from my father's farm, engaged in this respect my special attention. Their sources are not far apart, and they flow in opposite directions, on opposite sides of a low ridge, an old glacial moraine, a mile or two across. The Oatka Creek flows northward from this ridge, while the East Coy runs toward the southeast on the other side of it, both flowing ultimately into the same river, the Genesee.

It does not require a very careful observer to see that in these two streams the fishes are not quite the same. The streams themselves are similar enough. In each the waters are clear and fed by springs. Each flows over gravel and clay, through alluvial meadows, in many windings, and with willow and alders " in all its elbows." In both streams we were sure of finding trout, and in one of these the trout is still abundant. In both we used to catch the brook chub, or, as we used to call it, the " horned dace " (*Semotilus atromaculatus*) ; and in both were large schools of shiners (*Luxilus cornutus*) and of suckers (*Catostomus commersonii*). But in every deep hole, and especially in the mill ponds along the East Coy Creek, the horned pout (*Ameiurus melas*) swarmed on the mucky bottoms. In every eddy, or in the deep hole worn at the root of the elm trees, could be seen the sunfish (*Eupomotis gibbosus*), strutting in green and scarlet, with spread fins keeping intruders away from its nest. But in the Oatka Creek were found neither horned pout nor sunfish, nor have I ever heard that either has been taken there. Then, besides these nobler fishes, worthy of a place on every schoolboy's string, we knew by sight, if not by name, numerous smaller fishes, darters (*Catonotus flabellare* and *Boleosoma olmstedi*) and minnows (*Rhinichthys atronasus*), which crept about in the gravel on the bottom of the East Coy but which we never recognized in the Oatka.

There must be a reason for differences like these, in the streams themselves or in the nature of the fishes. The sunfish and the horned

pout are home-loving fishes to a greater extent than the others which I have mentioned; still, where no obstacles prevent, they are sure to move about. There must be, then, in the Oatka some sort of barrier or strainer which, keeping these species back, permits others more adventurous to pass; and a wider knowledge of the geography of the region showed that such is the case. Farther down in its course, at Rock Glen, the Oatka falls over a ledge of rock, forming a considerable waterfall. Still lower down its waters disappear in the ground, sinking into some limestone cavern, from which they reappear, after about 6 miles, in the large springs at Caledonia. Either of these barriers might well discourage a quiet-loving fish; while the trout and its active associates have sometimes passed them, else we should not find them in the upper waters in which they alone form the fish fauna. This problem is a simple one; a boy could work it out, and the obvious solution seems to be satisfactory.

Since those days I have been a fisherman in many waters, not an angler exactly, but one who fishes for fish, and to whose net nothing large or small ever comes amiss; and wherever I go I find cases like this.

We do not know all the fishes of America yet, nor all those well that we have named and know by sight; still this knowledge will come with time and patience, and to procure it is a comparatively easy task. It is also easy to ascertain the more common inhabitants of any given stream. It is difficult, however, to obtain negative results which are really results. You can not often say that a species does not live in a certain stream. You can only affirm that it has not yet been found there, and you can rarely fish in any stream so long that you can find nothing that you have not taken before. Still more difficult is it to gather the results of scattered observations into general statements regarding the distribution of fishes. The facts may be so few as to be misleading, or so numerous as to be confusing; and the writers who have taken up this subject in detail have found both these difficulties to be serious. Whatever general propositions we may maintain must be stated with the modifying clause of "other things being equal"; and other things are never quite equal. Doctor Wilder's saying that "Nature abhors a generalization" is especially applicable to all discussions of the relations of species to environment.

The same problems, of course, come up in each of the other continents and in all groups of animals or plants; but most that I shall say now will be confined to the question of the dispersal of fishes in the fresh waters of North America. The broader questions of the boundaries of faunæ and of faunal areas I shall bring up only incidentally.

The first discussion of the dispersion of fresh-water fishes in America was begun in 1850 in Professor Agassiz's volume on Lake Superior. In his later paper[3] (1854), on the fishes of the Tennessee River, he outlines certain questions to be answered. The river rising in the mountains of Virginia and North Carolina (latitude 37°) as the Holston, Clinch, and French Broad, flows rather swiftly southwesterly to northern Alabama (latitude 34° 25′), thence northwesterly to the Ohio, which it enters in the same latitude (37°) as its source, but naturally at a much lower elevation. Are the fishes of the Tennessee the same throughout its extent? If so, water communication is the chief factor in their general distribution. Again, are the differences mainly controlled by the elevation? Or is their presence due to climatic differences?

In the extensive collections in the Tennessee Basin made by the writer and his associates we find ample evidence of the effects of each of these factors. Open communication for a long period is the most vital, especially with large or free-swimming fishes. For the smaller fishes, darters, minnows, etc., isolation with segregation gives rise to numerous geminate or twin forms, in the Allegheny Mountains on the one hand and the Ozarks on the other, the Mississippi River serving as an obstacle to their dispersion rather than, as with the large fishes, being the chief vehicle of distribution. The difference in species in the south bend of the river brings in a few species of warmer waters, contrasting with those of the mountain waters of the French Broad.

In an excellent memoir on the fishes of the Allegheny region (1868), Prof. Edward D. Cope has some pertinent suggestions:

As most fresh-water fishes perish in salt water, our present river faunas date from the last submergence, as also from the last period of glacial cold. The latter condition would drive species it did not destroy to the low waters along the coast. Cope concludes that "the distribution of fresh-water fishes is governed by laws similar to those controlling other terrestrials, in spite of the seemingly confined nature of their habitat." This is doubtless true, in general, although in very many cases, each different river basin possesses species, geminate to those in the next basin, but not quite identical, the difference being due to failure for long periods to interbreed with the mass of the parent species. But in many cases the fishes of these basins are identical. In one case, which is probably typical of many, river fishes were found to enter the sea at times of high water, apparently returning to some other stream emptying in the same neighborhood. The apparent interchange was plainly seen by the writer in the rivers of Escambia and Perdido of western Florida.

[3] "On fishes from Tennessee River, Alabama." American Journal of Science and Arts, 2d series, XVII, 1854, p. 76.

In other cases many large rivers, draining very different districts and perhaps flowing into different oceans, have their source close together in the same mountain regions. From one source to another we may have a marshy tract, transversable at high water by the few species which ascend thus far.

The following examples show how transfer of species may be accomplished, and that we need not be left to draw on the imagination to invent possible means of transit.

There are few watersheds in the world better defined than the mountain range (Dovrefjeld) which forms the "backbone" of Norway. I lately climbed a peak in this range, the Suletind. From its summit I could look down into the valleys of the Lara and the Bagna, flowing in opposite directions to opposite sides of the peninsula. To the north of the Suletind is a large double lake called the Sletningenvand. The maps show this lake to be one of the chief sources of the westward-flowing river Lara. This lake is in August swollen by the melting of the snows, and at the time of my visit it seemed to be the source of both these rivers. From its southeastern side flowed a large brook into the valley of the Bagna, and from its southwestern corner, equally distinctly, came the waters which fed the Lara. This lake, like similar mountain ponds in all northern countries, abounds in trout; and these trout certainly have for part of the year an uninterrupted line of water communication from the Sognefjord on the west of Norway to the Christianiafjord on the southeast—from the North Sea to the Baltic. Part of the year the lake has probably but a single outlet, through the Lara. A higher temperature would entirely cut off the flow into the Bagna, and a still higher one might dry up the lake altogether. This Sletningenvand, with its two outlets on the summit of a sharp watershed, may serve to show us how other lakes, permanent or temporary, may elsewhere have acted as agencies for the transfer of fishes. We can also see how it might be that certain mountain fishes should be so transferred while the fishes of the upland waters may be left behind. In some such way as this we may imagine that various species of fishes have attained their present wide range in the Rocky Mountain region; and in similar manner perhaps the eastern brook trout (*Salvelinus fontinalis* Mitchill) and some other mountain species (*Hydrophlox rubricroceus* Cope, *Rhinichthys atronasus* Mitchill) may have been carried across the Alleghenies.

It is well known that a marshy upland in Brazil separates the valley of La Plata from that of the Amazon, and its channels permit the free movement of fishes from the Paraguay River to the Tapajos. In the World War an effort was made to transfer armament by this means from the Amazon to Germans in southern Brazil. It is well

known that through the Cassiquiare River the Rio Negro, another branch of the Amazon, is joined to the Orinoco River. It is thus evident that almost all the waters of eastern South America form a single basin, so far as the fishes are concerned.

As to the method of transfer of the trout from the Columbia to the Missouri we are not now left in doubt.

To this day, as the present writer and later Evermann and Jenkins[4] have shown, the Yellowstone and Snake Rivers are connected by two streams crossing the main divide of the Rocky Mountains from the Yellowstone to the Snake across the Two-Ocean Pass (pl. 2).

Professor Evermann has described the locality as follows:

Two-Ocean Pass is a high mountain meadow, about 8,200 feet above the sea and situated just south of the Yellowstone National Park, in longitude 110° 10′ W., latitude 44° 3′ N. It is surrounded on all sides by rather high mountains except where the narrow valleys of Atlantic and Pacific Creeks open out from it. Running back among the mountains to the northward are two small canyons down which come two small streams. On the opposite side is another canyon down which comes another small stream. The extreme length of the meadow from east to west is about a mile, while the width from north to south is not much less. The larger of the streams coming in from the north is Pacific Creek, which, after winding along the western side of the meadow, turns abruptly westward, leaving the meadow through a narrow gorge. Receiving numerous small affluents, Pacific Creek soon becomes a good-sized stream, which finally unites with Buffalo Creek a few miles above where the latter stream flows into Snake River.

Atlantic Creek was found to have two forks entering the pass. At the north end of the meadow is a small wooded canyon down which flows the North Fork. This stream hugs the border of the flat very closely. The South Fork comes down the canyon on the south side, skirting the brow of the hill a little less closely than does the North Fork, the two, coming together near the middle of the eastern border of the meadow, form Atlantic Creek, which after a course of a few miles flows into the upper Yellowstone. But the remarkable phenomena exhibited here remain to be described.

Each fork of Atlantic Creek, just after entering the meadow, divides as if to flow around an island, but the stream toward the meadow, instead of returning to the portion from which it had just parted, continues its westerly course across the meadow. Just before reaching the western border the two streams unite and then pour their combined waters into Pacific Creek; thus are Atlantic and Pacific Creeks united and a continuous waterway from the Columbia via Two-Ocean Pass to the Gulf of Mexico is established.

Pacific Creek is a stream of good size long before it enters the pass, and its course through the meadow is in a definite channel; but not so with Atlantic Creek. The west bank of each fork is low and the stream is liable to break through anywhere and thus send part of its water across to Pacific Creek.

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[4] Evermann, "A reconnaissance of the streams and lakes of western Montana and northwestern Wyoming," in Bull. U. S. Fisheries Commission, XI, 1891, 24–28, pls. 1 and 2; Jordan, "The story of a strange land," in Popular Science Monthly, February, 1892, 447–458; Evermann, "Two-Ocean Pass," in Popular Science Monthly, June, 1895, with plate.

TWO-OCEAN PASS, LOOKING EAST

After Evermann, Popular Science Monthly, June, 1895)

It is probably true that one or two branches always connect the two creeks under ordinary conditions, and that following heavy rains or when the snows are melting a much greater portion of the water of Atlantic Creek crosses the meadow to the other side.

Besides the channels already mentioned, there are several more or less distinct ones that were dry at the time of our visit. As already stated, the pass is a nearly level meadow covered with a heavy growth of grass and many small willows 1 to 3 feet high. While it is somewhat marshy in places it has nothing of the nature of a lake about it. Of course, during wet weather the small springs at the borders of the meadow would be stronger, but the important facts are that there is no lake or even marsh there and that neither Atlantic nor Pacific Creek has its rise in the meadow. Atlantic Creek, in fact, comes into the pass as two good-sized streams from opposite directions and leaves it by at least four channels, thus making an island of a considerable portion of the meadow. And it is certain that there is, under ordinary circumstances, a continuous waterway through Two-Ocean Pass of such a character as to permit fishes to pass easily and readily from Snake River over to the Yellowstone, or in the opposite direction. Indeed, it is quite possible, barring certain falls in the Snake River, for a fish so inclined, to start at the mouth of the Columbia, travel up that great river to its principal tributary, the Snake, thence on through the long, tortuous course of that stream, and, under the shadows of the Grand Teton, enter the cold waters of Pacific Creek, by which it could journey on up to the very crest of the great Continental Divide, to Two-Ocean Pass; through this pass it may have a choice of two routes to Atlantic Creek, in which the downstream journey is begun. Soon it reaches the Yellowstone, down which it continues to Yellowstone Lake, then through the lower Yellowstone out into the turbid waters of the Missouri; for many hundred miles it may continue down this mighty river before reaching the Father of Waters, which will finally carry it to the Gulf of Mexico—a wonderful journey of nearly 6,000 miles, by far the longest possible fresh-water journey in the world.

We found trout in Pacific Creek at every point where we examined it. In Two-Ocean Pass we found trout in each of the streams and in such positions as would have permitted them to pass easily from one side of the divide to the other. We also found trout in Atlantic Creek below the pass, and in the upper Yellowstone they were abundant. Thus it is certain that there is no obstruction, even in dry weather, to prevent the passage of trout from the Snake River to Yellowstone Lake; it is quite evident that trout do pass over in this way; and it is almost certain that Yellowstone Lake was stocked with trout from the west via Two-Ocean Pass (*Salmo clarki* Richardson).

The Sierra Nevada constitutes a very important barrier to the diffusion of species. This is, however, broken by the passage of the Columbia River, and many species thus find their way across it. That the waters to the west of it are not unfavorable for the growth of eastern fishes is shown by the fact of the rapid spread of the common eastern catfish (*Ameiurus nebulosus* Le Sueur and *Villarius catus* Linnaeus), or horned pout, when transported from the Schuylkill to the Sacramento. The two species of catfish are now among the important food fishes of the San Francisco markets, and with the Chinamen, their patron, they have gone from California to

Hawaii. In like fashion the large-mouthed black bass is now frequent in California lakes, as is also the blue-green sunfish (*Apomotis cyanellus*), introduced as food for the bass.

The mountain mass of Mount Shasta is, as already stated, a considerable barrier to the range of fishes, though a number of species find their way around it to the sea. The lower and irregular ridges of the Coast Range are of small importance in this regard, as the streams of their east slope reach the sea on the west through San Francisco Bay. Yet the San Joaquin contains a few species not yet recorded from the smaller rivers of southwestern California.

The main chain of the Alleghenies forms a barrier of importance separating the rich fish fauna of the Tennessee and Ohio Basins from the scantier faunæ of the Atlantic streams. Yet this barrier is crossed by many more species than is the case with either the Rocky Mountains or the Sierra Nevada. It is lower, narrower, and much more broken, in New York and Pennsylvania; and in Georgia there are several streams which pass through or around it. The much greater age of the Allegheny chain, as compared with the Rocky Mountains, seems not to be an element of much importance in this connection. Of the fish which cross this chain the most important is the brook trout (*Salvelinus fontinalis*), which is found in all suitable waters from Hudson Bay to the head of the Chattahoochee.

A few other species are locally found in the headwaters of certain streams on opposite sides of the range. An example of this is the little red "fallfish" (*Hydrophlox rubricroceus* Cope), found only in the mountain tributaries of the Savannah and the Tennessee. We may suppose the same agencies to have assisted these species that we have imagined in the case of the Rocky Mountain trout, and such agencies were doubtless more operative in the times immediately following the glacial epoch than they are now. Cope calls attention also to the numerous caverns existing in these mountains as a sufficient medium for the transfer of many species. I doubt whether the main chains of the Blue Ridge or the Great Smoky can be crossed in this way, though such channels are not rare in the subcarboniferous limestones of the Cumberland Range. In the brooks at the headwaters of the Roanoke River about Alleghany Springs in Virginia, fishes of the Kanawha Basin are found, instead of those characteristic of the lower Roanoke. In this case it is likely that we have to consider the results of local erosion. Probably the divide has been so shifted that some small stream with its fishes has been cut off from the Kanawha and transferred to the Roanoke.

The passage of species from stream to stream along the Atlantic slope deserves a moment's notice. It is under present conditions

impossible for any mountain or upland fish, as the trout or the miller's thumb (*Cottus bairdii* or *ictalops*) to cross from the Potomac River to the James, or from the Neuse to the Santee, by descending to the lower courses of the rivers, and thence passing along either through the swamps or by way of the sea. The lower courses of these streams, warm and muddy, are uninhabitable by such fishes. Such transfers are, however, possible farther north. From the rivers of Canada and from many rivers of New England the trout does descend to the sea and into the sea, and farther north the whitefish does this also. Thus these fishes readily pass from one river basin to another. As this is the case now everywhere in the North, it may have been the case farther south in the time of the glacial cold. We may, I think, imagine a condition of things in which the snowfields of the Allegheny chain might have played some part in aiding the diffusion of cold-loving fishes. A permanent snowfield on the Blue Ridge in western North Carolina might render almost any stream in the Carolinas suitable for trout, from its source to its mouth. An increased volume of colder water might carry the trout of the head streams of the Catawba and the Savannah as far down as the sea. We can even imagine that the trout reached these streams in the first place through such agencies, though of this there is no positive evidence. For the presence of trout in the upper Chattahoochee we must account in some other way.

It is noteworthy that the upland fishes are nearly the same in all these streams until we reach the southern limit of possible glacial influence. South of western North Carolina the faunæ of the different river basins appear to be more distinct from one another. Certain ripple-loving types are represented by closely related but unquestionably different species in each river basin, and it would appear that a thorough mingling of the upland species in these rivers has never taken place.

The best examples * of this are the following: In the Santee Basin are found *Notropis pyrrhomelas*, *Notropis niveus*, and *Notropis chloristius;* in the Altamaha, *Notropis xænurus* and *Notropis callisemus;* in the Chattahoochee, *Notropis hypselopterus* and *Notropis eurystomus;* in the Alabama, *Notropis cæruleus*, *Notropis trichroistius*, and *Notropis callistius.* In the Alabama, Escambia, Pearl, and numerous other rivers farther west is found *Notropis cercostigma.* This species descends to the sea in the cool streams of the pine woods. Its range is wider than that of the others, and in the rivers of Texas it reappears in the form of a closely related subspecies, *Notropis venustus.* In the Tennessee and Cumberland and in the rivers of

* All the species named in this paragraph belong to the subgenus *Erogala,* now placed under *Cyprinella,* to which it is nearer than to *Notropis.* In *Erogala* the dorsal has a large black area tipped in spring males with silver.

the Ozark Range is *Notropis galacturus;* and in the upper Arkansas *Notropis camurus*—all distinct species of the same general type. Northward, in all the streams west of the Alleghenies, and westward to the Des Moines and the Arkansas, occurs a single species of this type *Notropis whipplei*, varying eastward into *Notropis analostanus*. But this species is not known from any of the streams inhabited by any of the other species mentioned, although for all we know it may be the parent stock of them all.

With the lowland species of the southern rivers it is different. Few of these are confined within narrow limits. The streams of the whole South Atlantic and Gulf coast flow into shallow bays, mostly bounded by sand spits or sand bars which the rivers themselves have brought down. In these bays the waters are often neither fresh nor salt, or, rather, they are alternately fresh and salt, the former condition being that of the winter and spring. Many species descend into these bays, thus finding every facility for transfer from river to river. There is a continuous inland passage in fresh or brackish waters, traversable by such fishes, from Chesapeake Bay nearly to Cape Fear; and similar conditions exist in the coasts of Louisiana, Texas, and much of Florida. In Perdido Bay I have found fresh-water minnows (*Cyprinella cercostigma*, *Notropis xænocephalus*) and silversides (*Labidesthes sicculus*) living together with marine gobies (*Gobiosoma molestum*) and salt-water eels (*Myrophis punctatus*). Fresh-water alligator gars (*Lepisosteus tristœchus*) and marine sharks compete for the garbage thrown over from the Pensacola wharves. In Lake Pontchartrain the fauna is a remarkable mixture of fresh-water fishes from the Mississippi and marine fishes from the Gulf. Channel cats, sharks, sea crabs, sunfishes, and mullets can be found there together. It is therefore to be expected that the lowland fauna of all the rivers of the Gulf States would closely resemble that of the lower Mississippi; and this, in fact, is the case.

The streams of southern Florida and those of southwestern Texas offer some peculiarities connected with their warmer climate. The Florida streams contain a few peculiar fishes (*Jordanella*, *Rivulus*, *Heterandria*, etc.), while the rivers of Texas, with the same general fauna as those of farther north, have also a few distinctly tropical types (*Tetragonopterus*, *Cichlaurus*, etc.), immigrants from the lowlands of Mexico.

The fresh waters of Cuba are inhabited by fishes unlike those found in the United States. Some of these are evidently indigenous, derived in the waters they now inhabit directly from marine forms. Two of these are eyeless species (*Lucifuga* and *Stygicola*, fishes allied to the cusk, and belonging to the family of *Brotulidae*), inhabiting streams in the caverns. They have no relatives in the

fresh waters of any other region, the blind fishes (*Amblyopsis*, *Typhlichthys*, *etc.*), of our caves being of a wholly different type. Some of the Cuban fishes are common to the fresh waters of the other West Indies. Of northern types, only one, the alligator gar (*Lepisosteus tristœchus*), is found in Cuba, and this is evidently a filibuster immigrant from the coasts of Florida.

The low and irregular watershed which separates the tributaries of Lake Michigan and Lake Erie from those of the Ohio is of little importance in determining the range of species. Many of the distinctively northern fishes are found in the headwaters of the Wabash and the Scioto. The considerable difference in the general fauna of the Ohio Valley as compared with that of the streams of Michigan is due to the higher temperature of the former region, rather than to any existing barriers between the river and the Great Lakes. In northern Indiana the watershed is often swampy, and in many places large ponds exist in the early spring.

At times of heavy rains many species will move through considerable distances by means of temporary ponds and brooks. Fishes that have thus emigrated often reach places ordinarily inaccessible, and people finding them in such localities often imagine that they have "rained down." Once, near Indianapolis, after a heavy shower, I found in a furrow in a cornfield a small pike (*Esox vermiculatus* Le Sueur), some half a mile from the creek in which he should belong. The fish was swimming along in a temporary brook, apparently wholly unconscious that he was not in his native stream. Migratory fishes, which ascend small streams to spawn, are especially likely to be transferred in this way. By some such means any of the watersheds in Ohio, Indiana, or Illinois may be passed.

It is certain that the limits of Lake Erie and Lake Michigan were once more extended than now. It is reasonably probable that some of the territory now drained by the Wabash and the Illinois was once covered by the waters of Lake Michigan. The cisco (*Leucichthys sisco* Jordan) of Lake Tippecanoe, Lake Geneva, and the lakes of the Oconomowoc chain is evidently a modified descendant of the so-called lake herring (*Leucichthys artedi* Le Sueur). Its origin most likely dates from the time when these small deep lakes of Indiana and Wisconsin were connected with Lake Michigan. The changes in habits which the cisco has undergone are considerable. The changes in external characters are but trifling. The presence of the cisco in these lakes and its periodical disappearance—that is, retreat into deep water when not in the breeding season—have given rise to much nonsensical discussion as to whether any or all of these lakes are still joined to Lake Superior or Lake Michigan by subterranean channels. Several of the larger fishes (as *Lota maculosa; Percopsis omiscomaycus; Esox masquinongy*)

are occasionally taken in the Ohio River, where they are usually recognized as rare stragglers. The difference in physical conditions is probably the sole cause of their scarcity in the Ohio Basin.

FIG. 1.—Georgian Bay Lake Herring, *Leucichthys harengus* (Richardson). Collingwood, Georgian Bay

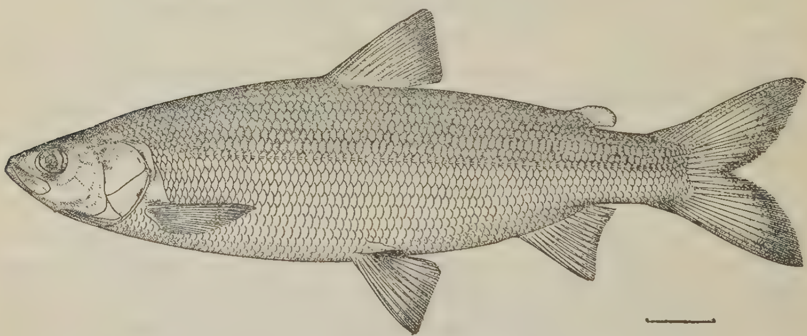

FIG. 2.—Common Lake Herring, *Leucichthys artedi* (Le Sueur). Lake Erie at Cleveland

FIG. 3.—Blackfin, *Leucichthys nigripinnis* Gill. Lake Michigan, Kenosha, Wis.

The similarity of the fishes in the different streams and lakes of the Great Basin of Utah is doubtless to be attributed to the general mingling of their waters which took place during and after the glacial epoch. Since that period the climate in that region has

grown hotter and drier, until the overflow of the various lakes into the Columbia Basin through the Snake River has long since ceased. These lakes have become isolated from each other, and some of them have become salt or alkaline and therefore uninhabitable. In some of these lakes certain species are now extinct which may still remain in others. In some cases, perhaps, the differences in surroundings may have caused divergence into distinct species of what was once one parent stock.[5] The suckers in Lake Tahoe and those in Utah Lake are certainly now different from each other and from those in the Columbia. The trout (*Salmo*

FIG. 4.—Tahoe Trout, *Salmo henshawi* Jordan. Lake Tahoe; this and the next are derived from *Salmo clarki*, the "cut-throat trout."

FIG. 5.—Utah Trout, *Salmo clarki utah*. Utah Lake

henshawi and *Salmo clarki utah*) in waters once connected are tangible species, while the whitefishes (*Prosopium williamsoni*) in the rivers show no differences at all. The differences in the present faunas of Lake Tahoe and Utah Lake are due to influences which have acted since the glacial epoch, when the whole Utah Basin was part of the drainage of the Columbia. But the separation of the Utah Lake, Bonneville must be much more recent than that of Lake Lahontan, which once covered much of Nevada.

[5] A most striking case of species formed by isolation is found in the three California golden trout, "*Salmo aquabonita*, *S. roosevelti*, (see pl. 1) and *S. whitei*.) shut off centuries ago by a trap dyke, from Kern River. Each is apparently derived from the Shasta rainbow, *Salmo shasta*, not from the present Kern trout, *Salmo gilberti*.

Connected perhaps with changes due to glacial influences is the presence in the deep waters of the Great Lakes of certain marine types,[6] as shown by Prof. Sidney I. Smith and others. One of these is a genus of fishes,[7] of which the nearest allies now inhabit the Arctic Seas. In his review of the fish fauna of Finland,[8] Prof. A. J. Malmgren finds a number of Arctic species in the waters of Finland which are not found either in the North Sea or in the southern portions of the Baltic. These fishes are said to "agree with their 'forefathers' in the glacial ocean in every point, but remain comparatively smaller, leaner, almost starved." Professor Lovén[9] also has shown that numerous small animals of marine origin are found in the deep lakes of Sweden and Finland as well as in the Gulf of Bothnia. These anomalies of distribution are expained by Lovén and Malmgren on the supposition of the former continuity of the Baltic through the Gulf of Bothnia with the glacial ocean. During the second half of the glacial period, according to Lovén—

> The greater part of Finland and of the middle of Sweden was submerged, and the Baltic was a great gulf of the glacial ocean, and not connected with the German ocean. By the gradual elevation of the Scandinavian Continent, the Baltic became disconnected from the glacial ocean and the Great Lakes separated from the Baltic. In consequence of the gradual change of the salt water into fresh, the marine fauna became gradually extinct, with the exception of the glacial forms mentioned above.

It is possible that the presence of marine types in our Great Lakes is to be regarded as due to some depression of the land which would connect their waters with those of the Gulf of St. Lawrence. On this point, however, our data are still incomplete.

To certain species of upland or mountain fishes the depression of the Mississippi Basin itself forms a barrier which can not be passed. The black-spotted trout,[10] very closely related species of which abound in all waters of northern Asia, Europe, and western North America, has nowhere crossed the basin of the Mississippi, although one of its species finds no difficulty in passing Bering Strait. The trout and whitefish of the Rocky Mountain region are all species different from those of the Great Lakes or the streams of the Allegheny system. To the grayling, the trout, the whitefish, the pike, and to Arctic and sub-Arctic species generally, Bering Strait has evidently proved no serious obstacle to diffusion; and it is not

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[6] Species of *Mysis* and other genera of Crustaceans, similar to species described by Sars and others, in lakes of Sweden and Finland.

[7] *Triglopsis thompsoni* Girard, a near ally of the marine sp. *Oncocottus quadricornis* L.

[8] Kritisk Ofversigt af Finlands Fisk-Fauna, Helsingfors, 1863.

[9] See Günther, Zoological Record for 1864, p. 137.

[10] *Salmo trutta* or *fario* L., in Europe; *Salmo labrax* Pallas, etc., in Asia; *Salmo irideus* Gibbons in streams of the Pacific coast; many derivatives of *Salmo clarki* Richardson, throughout the Rocky Mountain Range to the Mexican boundary, and the headwaters of the Kansas, Platte, and Missouri.

unlikely that much of the close resemblance of the fresh-water faunæ of northern Europe, Asia, and North America is due to this fact. To attempt to decide from which side the first migration came in regard to each group of fishes might be interesting; but without a wider range of facts than is now in our possession, most such attempts, based on guesswork, have little value. The interlocking of the fish faunas of Asia and North America presents, however, a number of interesting problems, for migrations in both directions have doubtless taken place.

One might go on indefinitely with the discussion of special cases, each more or less interesting or suggestive in itself, but the general conclusion in all cases is the same. The present distribution of fishes is the result of the long-continued action of forces still in operation. The species have entered our waters in many invasions from the Old World or from the sea. Each species has been sub-

Fig. 6.—Rainbow Trout, *Salmo irideus* Gibbons, male. Introduced to Vernia, Mo.

jected to the various influences implied in the term "natural selection," and also to concurrent effects of isolation and segregation, and under varying conditions its representatives have undergone many different modifications. Each of the 681 fresh-water species we now know in the United States may be conceived as making every year inroads on territory occupied by other species. If these colonies are able to hold their own in the struggle for possession, they will multiply in the new conditions, and the range of the species becomes widened. If the surroundings are different, new species or subspecies will be formed with time; and these new forms may again invade the territory of the parent species. Again, colony after colony of species after species may be destroyed by other species or by uncongenial surroundings.

The ultimate result of centuries on centuries of the restlessness of individuals is seen in the facts of geographical distribution. Only in the most general way can the history of any species be traced;

but could we know it all, it would be as long and as eventful a story as the history of the colonization and settlement of North America by immigrants from Europe. But by the fishes each river in America has been a hundred times discovered, its colonization a hundred times attempted. In these efforts there is no cooperation. Every individual is for himself, every struggle a struggle of life and death; for each fish is a cannibal, and to each species each member of every other species, even sometimes of its own, is an alien and a savage.

CONTRAST OF FAUNAS OF NORTH AMERICA AND EUROPE

We now recognize about 681 species of fishes as found in the fresh waters of North America, north of the Tropic of Cancer, these representing 36 of the natural families, as shown in Table 1.

TABLE 1.—*Showing approximately the composition of the fresh-water fish fauna of Europe, as compared with that of North America north of the Tropic of Cancer (see Fresh Water Fishes of Europe)*

Families		Europe	Northern North America
		Species	*Species*
Lamprey	Petromyzonidæ	3	8
Paddlefish	Polyodontidæ		1
Sturgeon	Acipenseridæ	10	6
Gar-pike	Lepisosteidæ		3
Bowfin	Amiidæ		1
Catfish	Siluridæ with Ameiuridæ	2	27
Sucker	Catostomidæ		51
Loach	Cobitidæ	3	
Carp	Cyprinidæ	61	230
Characin	Characinidæ		1
Moon-eye	Hiodontidæ		3
Herring	Clupeidæ	2	5
Gizzard shad	Dorosomidæ		3
Salmon and whitefish	Salmonidæ with Coregonidæ	10	50
Grayling	Thymallidæ	4	2
Trout perch	Percopsidæ		2
Blindfish	Amblyopsidæ		8
Killifish and top minnows	Cyprinodontidæ, etc	3	100
Mud minnow	Umbridæ	1	1
Pike	Esocidæ	1	5
Alaska blackfish	Dalliidæ		1
Eel	Anguillidæ	2	1
Stickleback	Gasterosteidæ	3	7
Silverside	Atherinidæ	2	12
Pirate perch	Aphredoderidæ		1
Elassoma	Elassomidæ		2
Sunfish	Centrarchidæ		37
Perch	Percidæ	11	4
Darters	Etheostomidæ		75
Bass	Moronidæ	1	4
Drum	Sciaenidæ		1
Surf fish	Embiotocidæ		1
Cichlid	Cichlidæ		5
Goby	Gobiidæ	2	6
Sculpin	Cottidæ	2	15
Blenny	Blennidæ	3	
Cod	Gadidæ	1	1
Flounder	Pleuronectidæ	1	
Sole	Soleidæ	1	1

Total: Europe, 22 families; 129 species. Northern North America, 36 families; 681 species.

According to Doctor Günther (Guide to the Study of Fishes, p. 243), the total number of species now known from the temperate regions of Asia and Europe is about 360. The fauna of India, south of the Himalyas, is much more extensive, numbering 625 species. This latter fauna bears little resemblance to that of North America, being wholly tropical in character, although largely made up from the same groups.

As to their habits, we may divide these species rather roughly into the four categories proposed by Professor Cope, or, as we may call them:

(1) Lowland fishes; as the bowfin,[11] pirate perch,[12] large-mouthed black bass,[13] sunfishes and some catfishes.

(2) Channel fishes; as the channel catfish,[14] the moon-eye,[15] gar-pike,[16] buffalo fishes,[17] and drum.[18]

(3) Upland fishes; as many of the darters, shiners and suckers, and the small-mouthed black bass.[19]

(4) Mountain fishes; as the brook trout, and many of the darters and minnows.

To these we may add the more or less distinct classes of—

(5) Lake fishes, inhabiting only waters which are deep, clear, and cold, as the various species of whitefish [20] and the Great Lake trout [21];

(6) Anadromous fishes, or those which run up from the sea to spawn in fresh waters, as the salmon,[22] sturgeon,[23] shad,[24] and striped bass [25];

(7) Catadromous fishes, like the eel,[26] which pass down to spawn in the sea; and

(8) Brackish-water fishes, which thrive best in the debatable waters of the river mouths, as most of the sticklebacks and killifishes.

As regards the range of species, we have every possible gradation from those which seem to be confined to a single river, and are rare even in their restricted habitat, to those which are in a measure cosmopolitan,[27] ranging everywhere in suitable waters.

Still, again, we have all degrees of constancy and inconstancy in what we regard as the characters of a species. Those found only in a single river basin are usually uniform enough; but the species having a wide range usually vary much in different localities. Such variations have at different times been taken to be the indications of as many different species. Continued explorations bring to light,

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[11] *Amia calva.*

[12] *Aphredoderus sayanus.*

[13] *Huro salmoides.*

[14] *Ictalurus punctatus.*

[15] *Hiodon tergisus.*

[16] *Lepisosteus osseus.*

[17] *Ictiobus bubalus, Megastomalobus cyprinella,* etc.

[18] *Aplodinotus grunniens.*

[19] *Micropterus dolomieu.*

[20] *Coregonus clupeiformis, Leucichthys artedi,* etc.

[21] *Cristivomer namaycush.*

[22] *Salmo salar.*

[23] *Acipenser,* sp.

[24] *Alosa sapidissima.*

[25] *Roccus saxatilis.*

[26] *Anguilla bostoniensis (rostrata)*

[27] Thus the chub sucker (*Erimyzon sucetta*) in some of its varieties ranges everywhere from Maine to Dakota, Florida, and Texas; while a number of other species are equally widely distributed.

from year to year, new species and new subspecies. But no study in fish groups permits the distinction of subspecies from species in the degree now possible among birds or mammals. We must await further studies for a consistent trinomial nomenclature in ichthyology. The number of new forms now discovered each year is often less than the number of recognized species which are each year proved to be untenable. Three complete lists of the fresh-water fishes of the United States have been published by the present writer. That of Jordan and Copeland [28] in 1876 enumerates 670 species. That of Jordan [29] in 1878 contains 665 species, and that of Jordan [30] in 1885, 587 species, although upward of 75 new species were detected in the nine years which elapsed between the first and the last list. Additional specimens from intervening localities are often found to form connecting links among the nominal species, and thus several supposed species become in time merged in one. The common channel catfish [31] of our rivers has been described as a new species not less than 25 times, on account of differences real or imaginary, but comparatively trifling in value.

Where species can readily migrate, their uniformity is preserved; but whenever a form becomes localized its representatives assume some characters not shared by the species as a whole. When we can trace, as we often can, the disappearance by degrees of these characters, such forms no longer represent to us distinct species. In cases where the connecting forms are extinct, or at least not represented in collections, each form which is apparently different must be regarded as a distinct species.

The variations in any type become, in general, more marked as we approach the Tropics. The genera are represented, on the whole, by more species there, and it would appear that the processes of specific change go on more rapidly under the conditions of life in the Torrid Zone.

We recognize now in North America 25 distinct species of fresh-water catfishes (Ameiuridæ), although 93 nominal species of these fishes have been from time to time described. But these 25 species are among themselves very closely related, and all of them are subject to a variety of minor changes. It requires no strong effort of the imagination to see in them all the modified descendants of some one species of catfish, not unlike our commoner "bull-head" (*Ameiurus*

[28] Check list of the fishes of the fresh waters of north America, by David Starr Jordan and Herbert E. Copeland. Bull. of the Buffalo Society of Natural History, 1876, pp. 133–164.

[29] A catalogue of the fishes of the fresh waters of North America. Bulletin of the United States Geological Survey, 1878, pp. 407–442.

[30] A catalogue of the fishes known to inhabit the waters of North America north of the Tropic of Cancer. Annual Report of the Commissioners of Fish and Fisheries for 1884 and 1885.

[31] *Ictalurus punctatus.*

nebulosus), an immigrant perhaps from South America, and which has now adjusted itself to its surroundings in each of our myriad catfish breeding streams.

The word "species," then, is simply a term of convenience, including such members of a group similar to each other as are tangibly different from others, which have endured in the gauntlet of life and are not known to be still connected with these by intermediate forms. Such connecting links we may suppose to have existed in all cases. We can only be sure that they do not now exist in our collections, so far as these have been carefully studied.

When two or more species of any genus now inhabit the same waters, they are usually species whose differentiation is of long standing—species, therefore, which can be readily distinguished from one another. When, on the other hand, we have "representative species" (better called geminate or twin species)—closely related forms, neither of which is found within the geograpical range of the other—we can with some confidence look for intermediate forms where the territory occupied by the one bounds that inhabited by the other. In very many such cases intermediate forms have been found; and such forms are considered as subspecies of one species, the one being regarded as the parent stock, the other as an offshoot due to separation under influences of different environment. Then, besides these "species" and "subspecies," groups more or less readily recognizable, there are varieties and variations of every grade, often too ill defined to receive any sort of name, but still not without significance to the student of the origin of species. Comparing a dozen fresh specimens of almost any kind of fish from any body of water with an equal number from somewhere else, one will rarely fail to find some sort of differences—in size, in form, in color. These differences are obviously the reflex of differences in the environment, due to segregation and to alterations in the stress of selection. The collector of fishes should recognize ontogenetic (not hereditary) alterations. It is usually not difficult to refer the effects to causes. Thus, fishes from grassy bottoms are darker than those taken from over sand, and those from a bottom of muck are darker still, the shade of color being, in some way not well understood, dependent on the color of the surroundings. Fishes in large bodies of water reach a larger size than the same species in smaller streams or ponds. Fishes from foul or sediment-laden waters are paler in color and slenderer in form than those from waters which are clear and pure. Again, it is often true that specimens from northern waters are less slender in body than those from farther south. Other things being equal, the more remote the localities from each other, the greater are these differences.

In our fresh-water fishes each species on an average has been described as new some three or four times, on account of minor variations, real or supposed. In Europe, where the fishes have been studied longer and by more different men, upwards of six or eight nominal species have been described for each one that is now considered tenable.

It is evident that the idea of a separate creation for each species of fishes in each river basin, as entertained by Agassiz, is wholly incompatible with our present knowledge of the specific distinctions or of the geographical distribution of fishes. There is an unbroken gradation in the variations from the least to the greatest—from the peculiarities of the individual, through local varieties, geographical subspecies, species, subgenera, genera, families, superfamilies, and so on, until all fishlike vertebrates are included in a single bond of union.

It is, however, evident that not all American types of fishes had their origin in America, or even first assumed in America their present forms. Some of these are perhaps immigrants from northern Asia, where they still have their nearest relatives. Still others are evidently modified importations from the sea; and of these some are very recent immigrants, landlocked species which have changed very little from the parent stock.

The character and possible origin of each of the 34 families of North American fresh-water fishes may be summarized briefly as follows:

The *lampreys* are evidently of marine origin, as the marine species are still anadromous. The fresh-water species, compared with the marine ones, are smaller in size and weaker in organization, and represent larval conditions or often arrests of development of the latter form. In most river forms, the loss of the upper part of the intestine is a sort of senile degradation.

The *paddlefish* is allied to extinct ganoid types. The group is now represented by one species in America and another in central Asia.

The *sturgeons*, like the lampreys, are anadromous. But three of the American species are now confined to the fresh waters, and two of these belong to peculiar genera (*Scaphirhynchus* and *Parascaphirhynchus*), which (like *Polyodon*) have representatives also in central Asia. As to whether the parent stock in either case is American or Asiatic, I know of no positive evidence.

The *gar pikes* and the *bowfins* are strictly American types allied to extinct ganoid forms, and doubtless developed from such in the waters they now inhabit.

The *catfishes* of America are all probably descendants of a common stock not closely allied to South American forms, but not finding any nearer relatives in Asia. The single species of this type

reported from China (*Ameiurus cantonensis*) is probably based on a specimen carried over from America.

The *suckers* are modified Cyprinidæ, probably developed in America, although one species has spread from Alaska to Siberia and another very peculiar form exists in China. Whatever its origin, this group is now one of the most characteristic of our fauna.

The *Cyprinidæ* of western America are more or less closely related to Old World types, and some of them, like the Old World species, reach a great size. East of the Rocky Mountains are found a multitude of species, mostly of small size and weak organization, which seem mostly to be degenerates or reduced representatives of European types, though for the most part having no immediate relatives among the latter. The majority of these species belong to a group of genera often united with *Notropis*, which is found only in America, and is one of the most characteristic of our fish fauna.

The *characins* belong to the Tropics, especially to South America. The single species which crosses the Rio Grande is an immigrant from Mexico. The same remarks apply also to the *cichlids*, a group especially characteristic of tropical America, one species of which reaches southern Texas.

The *moon-eyes* are characteristically American types, with no near relatives elsewhere in the world. Their ancestors were probably relics of the Cretaceous marine fauna.

The *herring* permanently resident in our fresh waters were originally landlocked representatives of forms still found in the sea along our coasts. Some species, as the shad, are anadromous, ascending rivers in the spring.

The *gizzard shad* is indifferently marine, anadromous, or landlocked, and is still extending its range in sluggish waters through the agency of canals.

The various forms of *salmon* and white-fish abound in the streams and lakes of all northern regions. The larger species are marine and anadromous, the smaller confined to lakes and brooks; but all seek streams or at least shallower waters for the purpose of spawning, and all which can do so enter the sea, becoming "salmon trout" or "steelheads." The whole group had probably a marine origin; the more strictly fresh-water species being, as is usually the case, smaller in size, weaker in organization, and with feebler dentition. It is often assumed that this group had its origin in the Atlantic, most likely in Europe, but equally great variety appears in the Northern Pacific.

The *trout perch* show a curious combination of characters of spiny and soft-rayed fishes. The two or three species are no doubt, as suggested by Agassiz, relics of an ancient fauna.

The *blindfishes* are also very unique in their organization. Two of the known species have well-developed eyes, and live in lowland streams and springs. Such are doubtless ancestors of the eyeless forms of the cave streams, but the immediate progenitors and relatives of the latter seem to be extinct. They were fresh-water forms, and of the same general stock as the ancestors of the killifishes, mud-minnows, and pike.

The *killifishes* and the allied families have their greatest abundance in tropical America, which is probably the place of their origin. Some of them are especially fishes of the brackish waters, never venturing far out to sea. Others ascend streams; and these frequent spring waters, and waters which are cold and clear. Others, nonmigratory, occur in spring waters only.

The three species of *mud minnow* are now very widely separated as to habitat, although very similar to each other in structure. One belongs properly to our Middle West, one to Atlantic shore drainage, the third to the streams of Austria. They are probably remains of a past fauna, in which the group was more fully represented. Our mud minnows (*Umbra limi* and *U. pygmæa*) are among the most tenacious of life of all fishes, and will often live for weeks in damp muck after the waters of a pond have evaporated.

Of the six or eight known species of *pike*, one is cosmopolitan, being spread over northern Asia and Europe as well as America, while the other species are somewhat restricted in their range. The common pike (*Esox lucius*) is probably the parent stock of all, but most likely originally American. The affinities of the mud minnow with the pike are not remote, and doubtless forms between the two have existed.

The *blackfish* (*Dallia pectoralis*) of Alaska is another relative of the mud minnow and pike. The single known species is found in Alaska and eastern Siberia and resists cold—even freezing—better than any other species. It, too, is probably an isolated relic of a disappearing group.

The *common eel* (*Anguilla* species) is more or less regularly catadromous, spawning in remote seas. Our single species is doubtless of marine origin. The same genus is widely diffused in eastern America, in Europe, and Asia, though curiously wanting on our Pacific coasts as well as in South America.

The *sticklebacks* and the *silversides* are seashore fishes, the former of cold, the latter of warm regions. Some species of each are now permanent residents of fresh water. The sticklebacks especially show all degrees of transition, the strictly fluviatile forms being as usual smaller in size and weaker in armature than the marine ones, even when belonging to the same species.

The *pirate perches* and the *Elassoma* are two very small families, related to each other, and distantly related perhaps to the sunfishes. They are probably remains of some older fauna.

The *sunfishes* are peculiarly North American, nothing similar being found in any other region. Their ancestry is probably to be sought among the marine *Serranidæ*, the large-mouthed black bass (*Huro salmoides*) being probably the member of the former group nearest the parent stock.

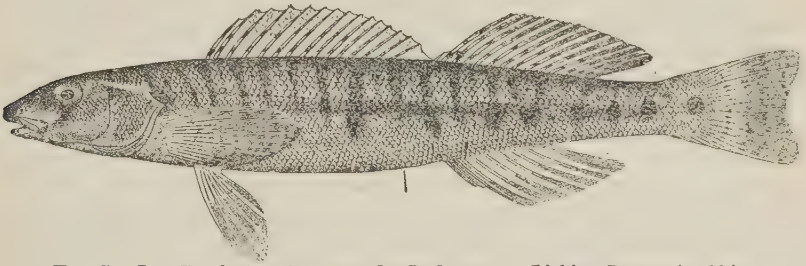

FIG. 7.—Log Perch, *Percina caprodes* Rafinesque. Licking Reservoir, Ohio.

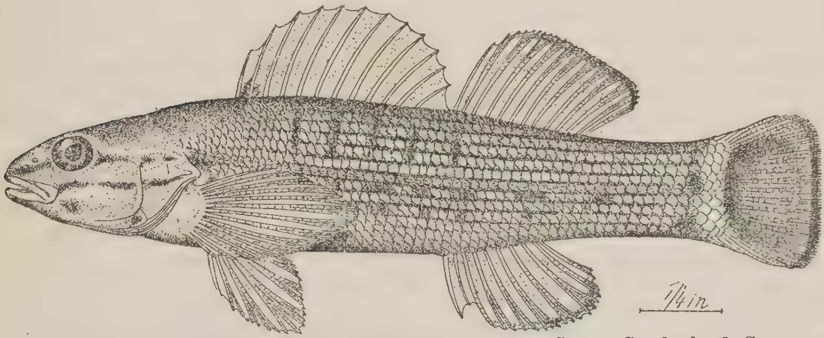

FIG. 8.—Blue-breasted Darter, *Nothonotus camurus* Cope. Cumberland Gap

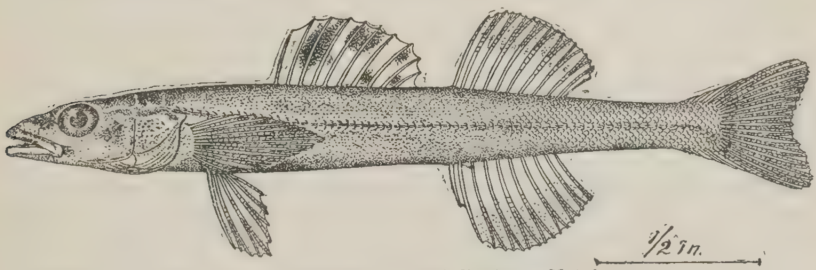

FIG. 9.—Sand Darter, *Ammocrypta beani* Jordan. Notalbany River, La.

The fresh-water (striped) *bass* (*Lepibema*, *Chrysoperea*) are evidently allied to the anadromous members of the same group.

The perch family is originally an offshoot from the sea bass, and certainly originally from Europe. The *Darters* (all American and east of the Rocky Mountains; none in tropical America) form a group (*Etheostoma*, *Boleosoma*, etc.) composed of small, brilliantly

colored perches, whose structure is especially modified for life on the rocky bottoms of small clear streams. The relations of these species to the typical perches have been admirably discussed by Prof. Stephen A. Forbes, from whose paper [32] I make the following quotations:

We must inquire, therefore, into the causes which have operated on a group of percoids to limit their range to such apparently unfavorable conditions, to diminish their size, to develop unduly the paired fins and reduce the air-bladder, to remove the scales of several species more or less completely, * * * and to restrict their food chiefly to a few forms (of insect larvæ and crustacea).

No species can long maintain itself anywhere which can not in some way find a sufficient food supply and also protect itself against its enemies. In its contests with its enemies it may acquire defensive structures or powers of escape sufficient for its protection, or it may become adapted to some place of refuge where other fishes will not follow. What better refuge could a harassed fish desire than the hiding places among stones in the shallows of a stream where the water dashes ceaselessly by with a swiftness few fish can stem? And if at the same time the refugee develop a swimming power which enables it to dart like a flash against the strongest current, its safety would seem to be insured. But what food could it find in such a place? Let us turn over the stones in such a stream, sweeping the roiled water at the same time with a small cloth net, and we shall find larva of *Chironomus* and small Ephermerids, and other such prey and little else—food too minute and difficult of access to support a large fish, but answering very well if our immigrant can keep down his size. * * * The limited supply of food early arrests the growth of the young; while every fish which passes the allowable maximum is forced for food to brave the dangers of the deeper waters, where the chances are that it falls a prey. On the other hand, the smaller the size of those with this alternative, the less likely will they be to attract the appetite of the small gar or other guerilla, which may occasionally raid their retreat, and the more easily will they slip about under stones in search of their microscopic game.

Like other fishes, the darters must have their periods of repose, all the more urgent because of the constant struggle with the swift current which their habitat imposes. Shut out from the deep, still pools and slow eddies where the larger species lurk, they are forced to spend their leisure on or beneath the bottom of the stream, resting on their extended ventrals and anal or wholly buried in the sand. * * *

Doubtless the search for food has much to do with this selection in a habitat. I have found that the young of nearly all species of our fresh-water fishes are competitors for food, feeding almost entirely on *Entomostraca* and the larvæ of minute Diptera. As a tree sends out its roots in all directions in search of nourishment, so each of the larger divisions of animals extends its various groups into every place where available food occurs, each group becoming adapted to the special features of its situation. Given this supply of certain kinds of food, nearly inaccessible to the ordinary fish, it is to be expected that some fishes would become especially fitted to its utilization. Thus the *Etheostomidæ* (darters) as a group are to be explained in a word by the hypothesis of progressive adaptation of the young of certain *Percidæ* to a peculiar place of refuge and a peculiar food supply.

Perhaps we may without violence call these the mountaineers among fishes. Forced from the populous and fertile valleys of the river beds and lake bottoms, they have taken refuge from their enemies in the rocky highlands, where the

[32] A catalogue of the native fishes of Illinois. Report of the Illinois Fish Commissioners, 1884, p. 95.

free waters play in ceaseless torrents, and there they have wrested from stubborn Nature a meager living. Although diminished in size by their continual struggle with the elements, they have developed an activity and hardihood, a vigor of life, and glow of high color almost unknown among the easier livers of the lower lands.

It is noteworthy that among the European genera of *Percidæ* one of them, Aspro (properly *Asper*), has assumed a similar habitat and adapted—apparently as a result of its surroundings—characters similar to those of *Etheostoma* and its allies. It is not likely that *Asper* is an ancestor of *Etheostoma* or *Percina*, still less likely that *Asper* is descended from any American genus. The similar development of the two is rather a case of analogous variation, the influence of similar conditions in different places on different organisms.

It is remarkable also that in mountain regions, in which no *Percidæ* are found, fishes very similar to the darters in appearance and habits though totally different in structure have by analogous agencies been developed. Loaches, catfishes, gobies, characins, sculpins in different parts of the world inhabit swift mountain streams and in a similar way become dwarfed and concentrated, taking the place in their respective habitats which the darters occupy in the waters of the Mississippi Valley.

By the same process of "analogous variation" the *Cichlidæ* of South America parallel the sunfishes of the United States, although in structure and in origin the two groups are diverse.

The single species each of *drum* (*Aplodinotus grunniens* Rafinesque), *surf fish* (*Hysterocarpus traski* Gibbons), and *cod* (*Lota lota* Linnaeus) found in our fresh waters are evidently immigrants from the sea, although not of very recent origin. The several fresh-water species of *Sculpin* have apparently come from two separate marine stocks—the one (*Cottus*) comparatively ancient and probably originating in the Pacific, the other *Triglopsis* more modern and descended from an Atlantic species (*Oncocottus quadricornis* L.). The former type is now diffused in all cold waters of North America, Europe, and northern Asia. The latter belongs only to the depths of our Great Lakes.

The *flounders* and *soles* when found in fresh waters are merely temporary sojourners from the sea.

THE MIND OF AN INSECT[1]

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Many a difference of opinion is merely a difference of definition. The "mind of an insect" will be but an empty phrase to him who defines the mind as something spiritual. On the other hand, if we agree to call the general physiology of the nervous system the mind, no dispute will arise when we speak of the mind of an insect, or of any other animal. But again, if we limit the term to the special nervous activities that involve consciousness, we have a middle ground with space for discussion at both ends, and since any proposition that leaves some room for difference of opinion is more interesting than one which is either too wide or too narrow, this conception of the mind will be a good definition from which to work, i. e., to argue. Next, we must have an understanding of what we mean by "consciousness." Here, however, the dictionaries relieve us of responsibility, for all definitions of consciousness amount to the one word, "awareness." True, to define a thing by its synonyms is only to shift from one foot to the other, but it is the best that can be done, since no one knows anything at all about the true nature of consciousness, and if one shoe fits and the other pinches, it is better to stand in the easy one.

I. THE SENSORY BASIS OF THE MIND

Awareness comes through the senses. In a last analysis, all that we know, all the premises of reason, and every incentive of volition depend upon sensory impressions—and the sense organs but present to us either conditions of the external environment or physical conditions within us, or at least an illusion of things that passes with us for the truth. To realize that the mind depends upon awareness of external things, or upon the memory of former conscious impressions, we have only to consider what our own minds would be like if we had no consciousness of anything present or past. A close inspection of our thoughts soon shows that all our mental processes, normal or abnormal, depend on things we have learned through the

senses. All the senses are not necessary to full development of the mind, for one sense, or its brain centers, can be trained to substitute for another, but a being without sight, hearing, smell, taste, touch, or feeling of any sort could not be conscious, or capable of mental action.

That consciousness itself is real can not be questioned; in fact, it is the only thing of which we can be sure, though we firmly believe that it represents within us external realities. To deny the evidence of the senses is to deny a cause for an effect. Each person, accepting his own consciousness as real, by analogy believes that his fellow beings possess consciousness, and, going to the bottom of the human scale, can not but step over and admit consciousness to the higher animals, for certainly dogs, cats, horses, monkeys, seals, and elephants may be allowed to have an awareness of things much as we have, and as for birds, few will deny consciousness to them, while, finally no one probably will seriously object to the idea that a fish may know something of what is going on about it. But, when it comes to the insects, the worms, and the rest of the invertebrates, we are inclined to draw the line, and to deny to all creatures of this kind the benefits of consciousness. However, we probably constitute a biased jury, certainly an ignorant one. Scientifically, which is to say, with an opinion based on knowledge, we can not anywhere draw a line through the animal kingdom and assert, to this side is consciousness, to that there is none. In view of the fact that all other things at the top of the animal scale are evolved from something at the bottom, it is logical to hold that consciousness in some degree is coexistent with life, that its rudiment, or its potentiality at least is present in the very lowest forms of living matter. Yet, it is conceivable that in the perfecting of cell activities, or in the development of mechanical complexity in the organization of animals, consciousness may have emerged somewhere or at various places in the course of evolution. However, the mechanical and chemical innovations adopted by animals at different stages in their progress have only broadened their powers and given greater possibilities for the utilization of inherent qualities; they have not created new physiological properties or any new kind of energy.

Though we may be forced, then, to a final belief in "panpsychism," it is most probably true that in the great majority of living things awareness is a mere potentiality, and that almost everywhere it has been held in abeyance while other properties of living matter have become dominant. It is only here and there, at the ends of certain phylogenetic lines of evolution, that consciousness crops out, manifesting itself for the most part in the mere rudiments of intelli-

gence, but developing finally in man into all the psychical qualities we attribute to the mind.

All *our* activities do not depend on mental or conscious processes. Our bodily functions go on without our personal attention, many of them without our being actively aware of them. Again, we are capable of doing many things automatically by purely reflex actions in which consciousness takes no part or has become unnecessary. But all nonconscious activities depend on direct stimulation, either one from without through an external sense organ, or one from within through an internal sense organ. Going lower than ourselves in the animal scale, we find that the nonconscious or reflex activities play an increasingly greater part in producing the actions of the animal, until, in the invertebrates, almost all the animal's doings are acts of the kind known as instinct, over which the creature has little more control than has a clock over the motions of its hands or its striking of the hours. We thus distinguish two coexistent modes of behavior in animals, which, though essentially different, are often so much alike in their external manifestations as to make it a difficult matter to decide whether an observed act is to be referred to one or to the other. The problem comes up particularly in the study of insects, especially in the social insects, whose acts in many ways appear to be so exemplary that moralists have often held them up as models for human conduct. Unfortunately, for the moral effect, human beings could not behave like ants or bees, because most of the insect's activities result from a nervous organization that works by a mechanism different from that which controls the characteristic behavior of man. The particularly human style of conduct is rudimentary in insects; the specifically insectan way of doing things was discarded long ago by the ancestors of the human race. Before proceeding with a study of insect behavior, the subject of this paper, let us attempt to get an idea of the probable mechanism of the two modes of action we would distinguish.

Protoplasm, the living substance of plant and animal cells, in its most elemental state possesses two important known properties. One property is sensitivity, the other reversibility. Sensitivity is just a name for the fact that living matter, under proper conditions, undergoes some kind of chemical change in the presence of variations in the environmental influences. For example, if there is a change in the intensity of light falling upon a live protoplasmic substance, or an alteration in the chemical composition, the density, or the pressure of the medium surrounding it, the protoplasmic matter undergoes an internal chemical change in response to the external change. In other words, the intramolecular forces of protoplasm

are so nicely balanced against the impinging forces of the environment that any change in the latter is immediately reflected by a change in the former. The response in the protoplasm, however, involves a partial decomposition of some of its molecules, resulting in the production of simpler substances of which some are eliminated, and in the liberation of energy. The second property of protoplasm, reversibility, is that by which living matter reverts to its original structure, and by which, therefore, it remains alive, for otherwise, after one effort, it would be dead. The original protoplasmic structure is restored by the taking of materials from the environment to replace those lost during the moment of response to the environmental change, and the reconstructive act involves an absorption of energy. These simple properties of protoplasm constitute the physiological basis of all animal activities.

Life, in its simplest terms, thus appears to consist of the production of energy by the upset of a certain equilibrium, and the restoration of the equilibrium to give the power of more energy production. As long as the double process can go on, life continues. All energy is motion of some sort, either of masses, or of the constituent molecules, atoms, or electrons of matter, or of the impalpable ether, and one form of it can be converted into any other form. If the structure of the protoplasmic mass is such as to permit of movement, its liberated energy may be converted into motion.

The kind of movement that an animal can make will depend entirely on the mechanical construction of its body. In most cases the motor principle is a mere change in shape of certain tissues, usually the contraction of a muscle cell or fiber. The variety of movements of which animals are capable, therefore, results not from differences in the type of engine or the kind of fuel but from differences in the connected mechanism. The principle of motion production is the same in an amœba, a worm, an insect, a bird, or a man.

We have seen that live protoplasm does not change except in response to the stimulus of some change in the environment. Muscle tissue, therefore, does not contract unless it is given a stimulus. But, in most animals, the muscles are removed from direct contact with the exterior, and are stimulated indirectly through a nerve that is connected with a specially sensitive end organ in the skin, which receives the stimulus direct from the environment and transmits it to the muscle through the nerve. In the many-celled animals, therefore, movement depends upon the presence of a receptor apparatus, or sense organ, a transmitting apparatus, or nervous system, and an effector apparatus, or muscle. By this mechanism, the animal responds with a movement to an external stimulus.

Now, it is clear that this diversity of fundamental structure gives a possibility of great diversification of action, because each of the three elements in the structural series can be endlessly modified and multiplied. In the first place, different kinds of sense organs may be developed, each sensitized to one particular group of environmental stimuli, thus giving the animal the power of responding separately to light, heat, odor, touch, etc. In the second place, the conducting apparatus can be so modified by the insertion of a switchboard mechanism into its course that, instead of transmitting direct from receptor to effector, it can send the stimulus from one receptor to this or that effector, or to many effectors at the same time. Finally, as already noted, the results in the effector apparatus can be immensely varied by multiplication of muscles and by diversification in the connected machinery of skeletal parts. Of the three divisions of the receiving-transmitting-operative system, the second is of particular importance, because, with the other two factors alike, two animals may act quite differently under the effect of the same stimulus through some slight difference in the nerve connections of the switch. The particular pattern of the connections determines the nature of the reflex. The acts of the animal are thus results of its specific anatomical structure; and physical heredity, therefore, will account for the fact that all individuals of a species respond in a characteristic manner to the same stimulus.

The nervous mechanism of response to stimuli, as understood from a study of the minute structure of nerve centers, may be simply explained by the diagrams in Figure 1. In a primitive reflex apparatus (A), a primary sense cell (SCl_1) lying in or beneath the skin makes a direct connection with a muscle cell (*Mcl*) by means of a prolongation, or fiber called the axon (*Nv*), from its inner surface. A sensory cell, together with its axon and any other branches, constitutes a neuron. In animals having a central nervous system (B), the primary sensory cell (SCl_1) is buried within the body, while a secondary sensory cell (SCl_2) sends an axon inward that makes connections with basal branches from the axon of the primary cell. A double system is thus established, in which the first cell and its branches constitute the motor neuron, and the second cell and its branches the sensory neuron. The central connection, or root associations, is called a synapse (*Syn*), and a nervous system having this structure (B, C, D) is said to be of the synaptic type to distinguish it from the direct or nonsynaptic type (A). The actual connections in the synaptic structure are usually more complicated than in the simple condition represented at B, through the interposition of an association neuron (*ACl*), as shown at C, branches of which make a two-way connection between the sensory roots and the motor roots.

The association system gives limitless possibilities for varying the response to a stimulus, for the single sensory impulse can be distributed to many motor neurons (D).

The conception outlined above of the anatomical basis of animal behavior is the foundation of most modern ideas as to the nature of

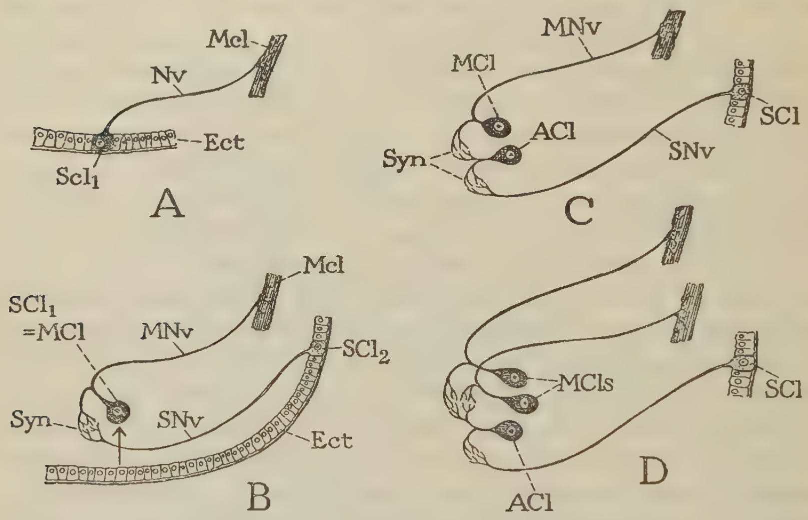

FIG. 1.—Diagrams showing the evolution of the reflex mechanism of the nervous system

A, theoretically primitive condition in which a sense cell (SCl_1) of the ectoderm (*Ect*) sends an axon process or nerve (*Nv*), to a muscle fiber (*Mcl*). The stimulation is here direct from the receptor (*SCl*) to the effector (*Mcl*), and the action of the latter is correspondingly limited.

B, the primary sense cell (SCl_1) removed from the ectoderm to the interior of the body, as indicated by the arrow, where it becomes a motor cell (*MCl*) of the central nervous system, and its axon going to the muscle (*Mcl*) becomes a motor nerve (*MNv*). The stimulus is here received indirectly by the motor nerve from another sense cell (SCl_2) of the ectoderm, which transmits its stimulus through its axon (*SNv*) to the motor nerve by way of a system of interlacing root branches from the two nerves, forming a *synapse* (*Syn*). A simple synaptic system of this kind is characteristic of the worms.

C, the synaptic nervous system of insects and of all higher animals is complicated by the interpolation of an association neuron between the sensory neuron and the motor neuron; the association, or internuncial, neuron consists of a cell (*ACl*) with branches making a two-way connection with the roots of the motor nerve (*MNv*) and those of the sensory nerve (*SNv*).

D, showing possibilities of development and resulting complexity of action in a central nervous system with association neurons, where, by the multiplication of nerve associations in the synapse, a sensory impulse can be distributed to various effectors.

the acts of living creatures called reflexes and instincts. An instinct is but a series of correlated reflexes, and in the insects as a class instinct has been carried to its highest point of perfection. Reflex acts performed alike by all members of a species in response to a given external stimulus are often called in general *tropisms;* but the term "tropism" was introduced by Loeb into the study of animal

behavior under a definition implying a special kind of reflex, or at least a special theory to explain reflexes. The specific act that an animal performs in response to a stimulus is called a *reaction*, and if the stimulus is a natural one the reaction usually plays some part in an instinct. All the factors in an instinct are not to be referred literally to external influences, for many stimuli have their origin within the animal's body, being the effect either of substances resulting from the ordinary physiological processes, or of special secretions thrown off from organs at a particular stage of activity that correlate one physiological action with another. These internal stimuli are not yet thoroughly understood, but in many cases they operate through special internal sense organs.

Mechanical reflexes and instincts serve admirably for maintaining the existence of a species in which individuals are abundant and can be readily replaced, for since they depend on an inherited organization that compels all members of the species to act alike in response to given conditions they do not provide for appropriate action in case of emergencies. Insects and most other animals with highly specialized instincts offset their emergency losses by a high reproductive rate. Instinct especially fits a species for communal life, for perfect communism entails an entire renunciation of individualism. Thus the beehive community or the ant-hill community is an organization of living things far superior in its organization to the best-organized human community; but the insect society can never evolve to anything higher than a more perfect beehive or a more perfect ant hill, except through the development of individuality, and individuality can not go far in a strictly communal society. It is surprising, therefore, to find that the power of individual action is best developed among insects in those very species that live a community life, such as the ants and the social bees and wasps. The explanation is that the higher faculties of these insects were developed first, and made communal life possible.

It appears that we have inadvertently encountered the other phase of animal behavior, already mentioned, before taking it up in logical sequence. This is the power of the individual to adjust its actions to whatever condition it encounters, the faculty ordinarily called "intelligence," and which we have assumed, for the sake of argument, is operative in a state of consciousness. Bees, for example, can distinguish differences of color, of odor, of form, and of position in objects; they can learn to associate one object with another, and to associate the presence of food with colors and odors, and they can remember these associations and act accordingly the next time they are encountered. But all these faculties in bees, and the similar facul-

ties possessed by wasps and ants are superimposed upon a general instinct, either the food-collecting instinct, the home-seeking instinct, or some other; they never lead the insects to the doing of new things or to the development of new habits that are not clearly modifications of old habits. If we seek to translate this kind of behavior into terms of nerve structure, the easiest solution that presents itself is the assumption that another switch has been introduced into the nerve circuit, which allows a sensory impression to modify the current in the established arc. Thus the food-collecting instinct may be made to operate in connection with the stimulus of red or of yellow, or in connection with a particular odor stimulus. Here, therefore, we have a possible mechanism of modifiable behavior, one which is not inherited in a set form, but which may become stabilized in the individual and give rise to a "habit" after repeatedly acting in the same way. It is possible that such an apparatus may involve no spark of consciousness; it is conceivable that it may act as mechanically as that of a fixed and inherited reflex or instinct. It apparently involves "memory" but memory in this case may be merely the mechanical facility of repeating what has been done before. That the insect distinguishes colors, forms, odors, and combinations of things may be explained as automatic responses to stimuli having no equivalent in consciousness. Yet, if we could invoke awareness, the feat of understanding the insect would be greatly simplified for us, accustomed as we are to explaining our own similar acts in terms of consciousness.

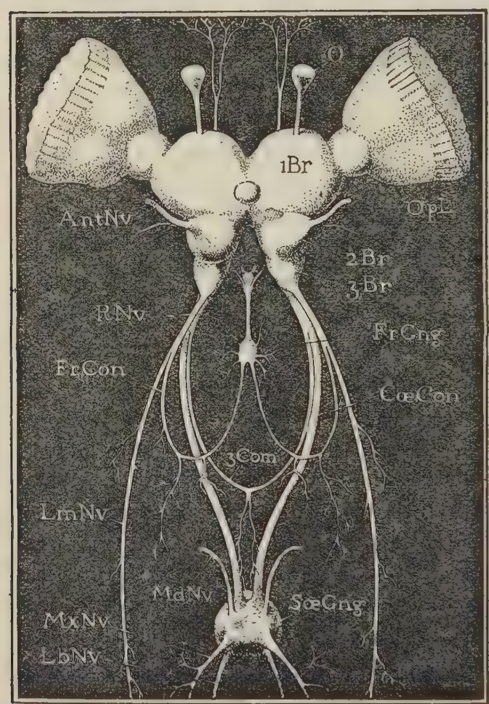

FIG. 2.—The brain and subœsophageal ganglion of a grasshopper (*Dissosteira carolina*) and their nerves, as seen after removal of the facial wall of the head

AntNv, antennal nerve; *1Br,* fore brain; *2Br,* mid brain; *3Br,* hind brain; *CœCon,* circumœsophageal connective; *3Com,* subœsophageal commissure of the hind-brain lobes; *FrGng,* frontal ganglion; *FrCon,* frontal ganglion connective with the brain; *LbNv,* labial nerve; *LmNv,* labral nerve; *MdNv,* mandibular nerve; *MxNv,* maxillary nerve; *O,* simple eye, or ocellus; *OpL,* optic lobe; *RNv,* recurrent nerve; *SœGng,* subœsophageal ganglion.

In the higher vertebrates, the seat of the mental faculties is undoubtedly in the cerebral hemispheres of the brain, where, beneath the cellular cortex, there are great masses of association fibers mingled with innumerable nerve endings from the sense organs and with the roots of nerves connecting with motor neurons going to all parts of the body. Within the insect brain likewise are various bodies of association fibers, which undoubtedly are important internuncial or correlating centers in the insect nervous system. (Fig. 3.) Some of these bodies vary in size and complexity within certain groups of insects corresponding in a general way to what might be regarded as the mental index of each species, judged from its known behavior. The correspondence is not close enough in all insects, however, to make it certain that any part of the insect brain is a definite "psychical center." Experiments have shown that the initiating impulse

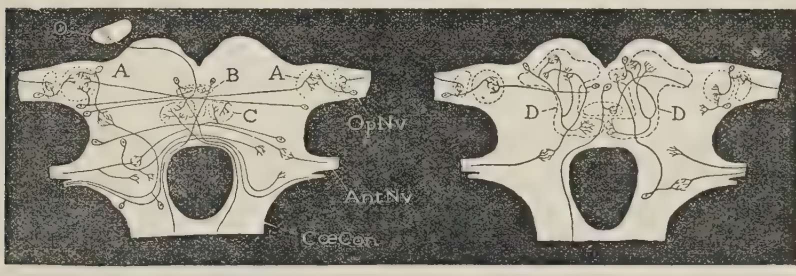

FIG. 3.—Cross-sections of the brain of a roach, showing diagrammatically the sensory centers of the brain, and the courses of the principal nerve tracts. (From Bretschneider)

A, A, centers of the optic ganglia; *AntNv,* base of antennal nerve; *B,* protocerebral bridge; *C,* central body; *CoeCon,* circumœsophageal connective; *D, D,* corpora pedunculata, or "mushroom bodies"; *O,* an ocellus, or simple eye; *OpNv,* optic nerve to compound eye

for the instinctive acts of insects originates in the brain, and all behavior that depends on the sense organs innervated from the brain necessarily is activated from the brain center; but, as will be shown later, the brain may otherwise be quite unnecessary for the proper performance of reflexes in a complicated instinct, if the latter can be stimulated by artificial means.

The evolution of the nervous mechanism within the invertebrates and the vertebrates shows only the development of one structural principle, that of the synapse—evidence that there has been also an evolution of only one functional principle, with nowhere the addition of a new and peculiarly "mental" element. The basic mechanism, however, has been capable of development along two divergent lines: One, specializing on the permanently closed type of structure, has developed the reflex method of function, which has produced its best results in the highly specialized instincts of insects;

the other, allowing of individual modifications and adjustments to varying conditions, has made possible the development of those faculties we call mental. Experimental studies of animal behavior have shown that the faculty of making individual adjustments to environmental changes runs down through the whole animal series, though in decreasing degree, and can be demonstrated to exist even in the Protozoa.

When a sense organ stimulates a nerve center, and the nerve center stimulates a muscle, what is it that goes through the connecting nerves? The answer to this question can not be given at present, though studies have been made and are still being carried on to determine the nature of the "nerve force" or "nerve impulse." It is undoubtedly a form of physical energy, but whether it is of the nature of a chemical reaction propagated through the nerve fiber or something akin to an electrical current involving an actual flow of electrons is not known. In any case, there is no reason for regarding it as a supernatural "vital force," since a current of electricity sent through the nerve will accomplish identical results in the motor apparatus.

All efforts, then, to discover anything but known forms of energy in the working of the nervous system fail. Yet the reality of consciousness can not be questioned. The nature of consciousness, however, baffles the understanding. All the known forms of energy may be conceived as motion; the physicists can account for the properties of light and its effects as some kind of movement in a hypothetical ether; heat can be explained as molecular activity, sound as wave motion, and chemical reactions are easily visualized as readjustments of electrons. If we say, however, as some would do, that consciousness also is a form of motion, a special kind of vibration in the electrons of nerve cells, we do nothing more than put words together, for the idea supposed to be expressed neither explains the activities of consciousness nor presents a conception that can possibly be accepted as a picture of awareness.

Consciousness, though real in itself, gives us no true information of our surroundings. From our sensation of light we should never guess that luminosity in nature is vibration in an ether medium; our auditory interpretation of sound is not that of atmospheric waves; heat causes no suggestion of molecular motion, and so on with every other sense by which we perceive some phase of the material environment. Most of our senses, then, are illusions, and in our senses we inhabit an unreal world, perhaps one all the better for being so, but unreal nevertheless, except in so far as we learn to interpret the truth by our reason or discover it by the use of invented instruments. Consciousness, therefore, did not originate for the purpose of giving

animals information concerning the nature of the environment. It is an internal reflection of the forms of energy in the environment and of the differences and changes in external things, not of the things themselves. Consciousness is but a sign indicative of external conditions; it does not present actuality any more than a traffic signal shows a line of passing cars or an open road.

A summary of the foregoing discussions and the writer's deduction of a working hypothesis are as follows: The fact of consciousness we can not escape; that it is an actual determining factor in human action seems equally certain; that it is a useful property of other animals is then but a logical inference. The idea that consciousness is a special endowment of certain animals is untenable. We can only conclude, therefore, that consciousness is potential at least in all living matter, that it may be feebly developed even in the lowest animals, but that it has become functional in the more highly organized members of several groups. It is impossible to determine by experimental methods where consciousness is active and where it is not. It is most

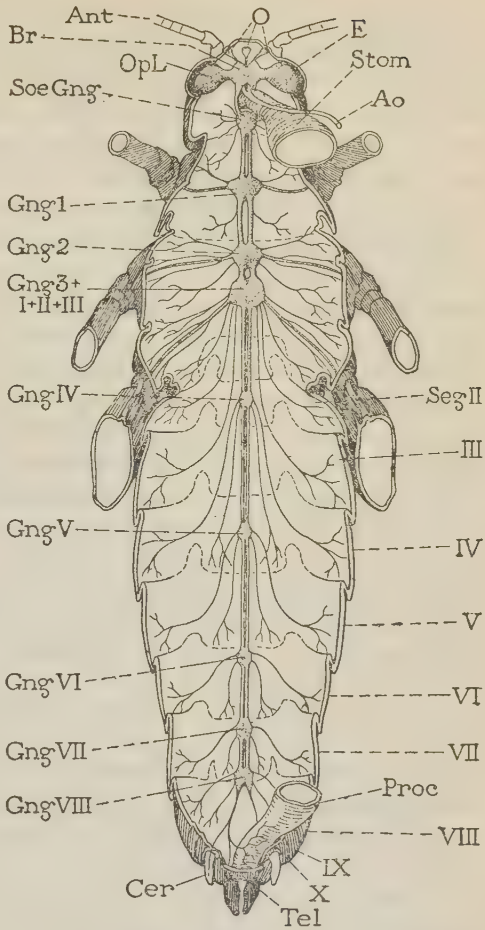

FIG. 4.—The nervous system of a grasshopper (*Dissosteira carolina*) as seen from above

In the head are the brain (*Br*), lying above the anterior part of the alimentary canal, or stomodeum (*Stom*), and the subœsophageal ganglion (*SœGng*) lying below the stomodeum. The brain gives off nerves to the simple eyes, or ocelli (*O*), to the two large compound eyes (*E*) on the sides of the head, and to the antennæ (*Ant*). Beneath the brain opens the anterior end of the dorsal blood vessel (*Ao*). In the body there is a chain of ventral ganglia (*Gng1–GngVIII*) representing the first eleven segments, but the large ganglion of the third segment is compounded of the ganglia belonging to the third, fourth, fifth, and sixth segments (*Gng3+I+II+III*), and the ganglion of the fourth abdominal segment (*GngIV*) lies in segment *II*, while that of segment *V* (*GngV*) is in segment *IV*. The ganglia of the last two segments (*IX* and *X*) are probably united with that of the eighth (*GngVIII*). The posterior part of the alimentary canal, the proctodeum (*Proc*) opens at the end of the body beneath a small plate (*Tel*), at the sides of which are the cerci (*Cer*).

reasonable to suppose that it becomes functional in connection with the development of the differential mechanism in the nervous system that allows the individual to modify its behavior according to the exigencies of circumstances. With consciousness once in possession of a mechanism of its own, its development has only been a matter of elaboration in the mechanism. From the first fruits of awareness in the form of differential perception, which is the beginning of intelligence, and of memory, which makes intelligence useful, there have been evolved, along with the development of the nerve mechanism of individual response, all those activities of consciousness that we call the mental faculties, and which in ourselves we feel can not be identified with any other property or activity of matter.

To limit our conception of the "mind" to conscious activities, as suggested above, is permissible as a theory; but since it is possible that a closer analysis of animal behavior will show that the facts do not conform with the conception, our discussion will be more complete, and will better meet the emergency, if it is widened to include a brief review of some of the more important so-called sensory reactions of insects, which are almost certainly automatic, and an examination of the nature of insect instincts, as well as examples of acts that may reasonably be regarded as intelligent.

II. REACTIONS OF INSECTS TO ENVIRONMENTAL STIMULI

Insects in general are affected by all the classes of things in nature that act as sensory stimuli on us, though every species is not receptive to all stimuli, and the effect of a particular stimulus varies in kind and in degree with different species.

In experimental studies on the so-called "senses" of insects we can determine only what the insect does in the presence of conditions that give us a sensory impression. If an insect goes to a certain odor, and avoids another, the mere fact of the reaction is all that we learn from the observation; by varying the conditions of the experiment we may discover less obvious facts, or find relations between external things and the reaction that were not suspected, but we can not tell what goes on within the insect. Hence, though it may be demonstrated that an insect reacts decisively to the stimulus of light, color, odor, taste, sound, or touch, we are unable to say literally that it sees, smells, tastes, hears, or feels, for these words imply states of consciousness known only in ourselves. We may say simply that the insect is sensitive to this or that stimulus; whether its sensitiveness is mere physiological sensitivity, or sensitivity accompanied by consciousness must be left an open question. On the other hand, no one can claim that the facts learned from experiment give reasons for denying consciousness to insects, and, as stated before, a belief in the

common origin of all forms of animal life almost demands as a corollary a belief in the universal presence or potentiality of consciousness. However, in dealing with the results of experimental work, we must take an attitude free from all bias of theory, lest our conclusions, or even our observations, be warped in the making.

Though the true nature of the insect mind can not be known to us, there is still ample reason for studying the reactions of insects to sensory stimuli; the information so obtained will give the closest approach to an understanding of the relation between insect behavior and the environment, a thing much to be desired for many practical reasons. The economic entomologist finds his efforts at the control of injurious species thwarted on all sides by the resources of the insects, resources which arise from mysterious powers with which the insects seem to be endowed. It is only by discovering the secrets of the insects that the practical entomologist will be able to put himself on an equal footing with his adversaries.

REACTION TO GRAVITY (GEOTROPISM)

Insects are highly responsive to gravity; they immediately right themselves when placed on their backs, which act, of course, might be attributed to a mere response to reversed contact, but the fact that insects maintain their position in the air during flight shows that they must have a well-developed sense of equilibrium. Besides this, insects know up from down in space, and many species are definitely geotropic, that is, on upright or inclined surfaces they go invariably upward or downward. The response has usually some relation to the normal feeding or other habits of the species. Young leaf-eating caterpillars, if hatched on the trunk of a tree, do not perish for lack of food; being negatively geotropic, their first continuous movements take them upward to the branches and outward to the foliage. Mature nymphs of the cicada, on reaching the surface of the earth after a long sojourn beneath its surface, are likewise negatively geotropic. They crawl skyward on the first upright surface they encounter. Positive geotropism is exhibited by many tree-inhabiting caterpillars just before the time of the pupal transformation, and the urge to go downward takes them to the earth, within which some species bury themselves to undergo their metamorphoses.

Considering the many ways by which insects react to gravity, and especially their sense of balance while on the wing, it is curious that no organs have been discovered in them, except in a few doubtful cases, to which a sense of equilibrium can be referred. Vertebrate animals have a well-developed organ of equilibrium in the semicircular canals and other structures of the inner ear, by which they are

enabled to maintain their balance at all times and the proper positions for swimming, running, and flying.

The organ that enables us to orient ourselves to the direction of gravity is not, strictly speaking, a sense organ of gravity, for it gives us no sensation corresponding with the stimulus. It is possible, then, that in our reactions to gravity we ourselves experience something of the nature of an automatic tropism. Though we are conscious of the muscle tensions which keep our heads upward, and of the pressure of our bodies on other surfaces, we have no actual gravity sensation analogous to the sensation of sight, sound, etc., and we certainly should never refer our faculty of equilibrium to the region of the inner ear if we had never studied physiology.

REACTION TO LIGHT (PHOTOTROPISM)

The multitude of insects seen swarming about street lamps on warm summer nights is proof sufficient that many species are strongly affected by light and go toward its source. The observation, of course, for reasons already given, does not prove that insects see light as we see it, or that nocturnal species seek the light because they find night life agreeable in its presence. For the most part insects found about lights are species that do not fly in the daytime; they are species that are attuned to dim lights. But, as Kennedy has interestingly pointed out, most insects must be hypersensitive to light on account of the relatively great size of their compound eyes. Compound eyes have to be large in order to be at all efficient as organs of vision. As a consequence the insect is overstimulated in the presence of unusually strong illumination, and nocturnal species swarm to bright lights if the nervous organization for making light responses is not provided with a controlling or inhibiting mechanism, which night-flying insects would not need under natural conditions. On coming into the immediate neighborhood of the light, however, some insects, Kennedy observes, are rendered inactive by the excessive degree of stimulation here encountered and sit motionless in the full glare.

Insects that react definitely to light are either positive or negative in their responses. Flies will leave a darkened room, roaches will go into it. Not many species, however, are attracted by total darkness, and a so-called negative reaction to light is in most cases a positive reaction to a low degree of light. In experiments it is often found that an insect is attracted by light up to a certain intensity, but is repelled if the intensity is increased. Most nocturnal insects are photopositive, as is shown by their attraction to lights at night. Many of them also exhibit positive light reactions if they are disturbed during the day.

Positive and negative responses to light by insects have usually some relation to the other factors of their general behavior, and the nature of the light reflex exhibited by any species may be presumed to be an adaptation to the insect's mode of life, to its manner of feeding, or to some other specific habit. The daytime seclusion by nocturnal species and the activity of diurnal species, however, can not in all cases be attributed to differences in their photic reactions. A nocturnal moth that has sat quietly all day in the darkness of some retreat in a room will come out in the evening, though the room is brightly lighted. Some singing Orthoptera confined indoors begin their music at a regular time each evening regardless of the illumination about them. Such observations have led to the idea that the activities of many insects are stimulated by a periodic activity in the nerve centers, dependent on some internal rather than on an external excitant. The subject needs further investigation, but there is much apparent evidence of periodicity, or rhythm, in the activities of insects, correlated with the time of change from day to night, which can not be satisfactorily explained as reaction to changing light intensity or to temperature.

The experiments of many workers on the "color sense" of insects, including those of Plateau, Lubbock, Forel, Turner, Lowell, Dobkiewicz, von Frisch, Lutz, and others, leave no doubt that at least some of the more highly organized insects distinguish differences of color; that is, they show by their reaction that different wave lengths of light have different effects upon them. The honeybee has been the principal subject of experiments on insect color vision, and it has been demonstrated repeatedly that bees can be trained to associate a certain color with food, and that they will return successively to an object of the same color in their subsequent search for more food. The results of such experiments, as already conceded, can not be taken as evidence that bees have color sensations, or if they do, that their sensations are the same as ours, and yet, since "red" or "blue" or "green" have each a definite physical basis, there is no reason why the psychical equivalent of each might not be the same wherever produced.

Insects that exhibit the power of color discrimination are not generally sensitive to all the colors of the spectrum that we see, most species being indifferent at least to certain colors; but on the other hand many insects unquestionably react to ultra-violet rays, which are entirely invisible to us. It has been shown by Lutz that some flowers reflect ultra-violet rays, while others do not, and Lutz has pointed out that as a consequence the color scheme of nature must be quite different to a creature able to see ultra-violet than it is to us.

Therefore, the results of experiments judged by our own color perception are likely to lead to erroneous conclusions concerning the color vision of insects.

General experiments on the perception of light or other stimuli by animals give us little more than a basis for estimating the functional limits of the receptive and sensory faculties; they do not tell us in most cases anything concerning the nature of the nervous mechanism that produces the reaction. By a more circumscribed type of experimentation, a group of investigators interested particularly in understanding the response of the organism have sought for evidence concerning the nature of the relations between the sense organs and the muscles that control the reaction. The strictly mechanical theory of tropisms, as proposed by Loeb, assumes that the animal goes toward or away from the source of a stimulus by the continuous action of the stimulus operating alike on both sides of the bilaterally symmetrical body. The behavior of many animals, of insects particularly, appears to be closely in accord with the terms of this theory. One of the most convincing pieces of evidence in favor of it in entomology is the well-known fact that an insect after having one eye covered with an opaque substance progresses or turns in circles in the directions of the open eye. Some investigators have found, however, that these "circus movements" are not invariable in all cases where an insect's sight is made unilateral, and that some species that turn in circles at first, after a time learn to orient themselves fairly well with one eye only. If the light entering either eye affects directly the movements of the legs on that side of the body, the response should be observable if the insect is held up with its legs free. Experiments made by Mast on flies suspended by the wings, however, showed that a varying light stimulus produces no reaction in the legs. From this and many other experiments on the behavior of insects exposed to controlled light stimuli, Mast concludes that any hypothesis "that demands balanced action in the receptors and locomotor appendages on opposite sides does not fully account for orientation in insects." He believes that there is a differential effect of the stimulus in the eyes and that orientation in insects is dependent on a series of coordinated reflexes more complex than that assumed by the theory of direct tropistic action.

The blowfly maggot has been used by several investigators as a subject for studying the method by which an insect orients itself to light. When the maggot crawls it proceeds by a series of alternating stretchings and contractions, while the anterior end of the body is swayed regularly from side to side. The maggot has no eyes, but its anterior end is very sensitive to light; its usual responses are negative. Herms, Mast, and Holmes have argued that the sidewise move-

ments of the head end of the fly larva allow the creature to perceive differences in the intensity of light at different angles; by avoiding the stronger sensations as much as possible, therefore, the maggot, when once set in motion by the light stimulus, crawls automatically away from the light source. This conception of the mechanism of orientation substitutes for the idea of the mechanical effect of a continuous action of the stimulus the idea of the perception of a change of intensity in the stimulus and a regulation of movements accordingly. As Holmes states it, "of a number of random movements in all directions, only those are followed up which bring the animal out of the undesirable situation."

It is difficult to avoid injecting the idea of conscious perception into the interpretation of experiments on differential perception, but, as Bouvier points out, this less direct form of orientation toward or away from a stimulus may be seen as but an automatic response resulting from a combination of tropisms and differential sensitivity. The facts observed in such cases are characteristic of all members of a species; there is no individuality of response, no alteration of it from experience.

REACTION TO HEAT (THERMOTROPISM)

Insects are definitely responsive to changes in temperature, but their thermic reactions are probably caused by the physiological effect of heat in their tissues, since insects are not known to have specific temperature receptive organs. Because insects have no means of conserving the heat produced in their bodies, the continuance of their metabolic processes depends upon heat received from the outside, and therefore insects in general are most active in warm weather or where they find artificial heat. The small size of their bodies makes insects particularly subject to loss of heat by radiation, for the smaller the animal the greater in proportion is the extent of its exposed surface. If an insect had to keep warm all the time it would exhaust itself by eating, for Kennedy has calculated that if an insect consumed a quantity of energy-forming food the same in proportion to its surface exposure as that consumed by a mouse or a man it would have to eat six and one-fourth times its weight in food every day. This law of inverse relation between size and heat radiation, however, is modified by many other factors; otherwise we should find the larger insects active at lower temperatures than the smaller ones. The activity of different species, in fact, shows a considerable range of tolerance to low temperatures, irrespective of size; many very small flies appear early in spring before the end of cold weather, and the moths of the fall cankerworms emerge from the ground to lay their eggs late in the fall or early in winter at northern latitudes.

Most insect species are adjusted to a definite optimum temperature within which they do their best work.

REACTION TO HUMIDITY (HYGROTROPISM)

Insects are highly sensitive to the degree of moisture in the air, and it is probable that humidity sensitiveness is an important factor in determining the geographical distribution of many species. Reactions to humidity must come from the general physiological effect of moisture on the insects' tissues, and loss of body moisture by evaporation will follow the same rule as radiation of heat, being proportioned to the surface, and therefore greatest in small animals, unless the latter are protected against it, as are insects with their hard, impervious body covering. Many insects, however, that do not take liquids as a part of their regular diet eagerly drink water when they can get it.

REACTIONS TO SMELL AND TASTE (CHEMOTROPISM)

Smell and taste, for the most part, are quite different sensations with us, but their stimuli would appear to be in many cases the same if they consist of disengaged molecules or other particles (ions) of the substances perceived. The faculties of gustation and olfaction are commonly called the chemical senses, and their receptive organs are termed chemoreceptors, implying a sensitiveness to the chemical properties of the stimulating substances. The terms are to be recommended, however, chiefly for their convenience, since they assume a greater knowledge than we yet have concerning the action of odor stimuli, and they would imply that odor and taste stimuli alone have a "chemical" effect on the receptor cells.

In vertebrates, the receptive organs of taste and smell always occur on moist membranes in the mouth and nasal passages, and it is therefore commonly assumed that moisture is a necessary condition for the action of smell and taste stimuli. There can be no question that insects are highly sensitive to odors, but all their sense organs, except those of the preoral cavity and the alimentary canal, are situated on dry external surfaces. The results, or interpretations, of experiments made by different workers trying to determine the location of the organs of smell in insects vary so much that at present we can not accept any particular generalization as fully expressing the truth. It seems probable that the olfactory organs are not confined to any one part of the insect, but occur in various places. So many different kinds of sense organs are distributed over the body and the appendages of insects, however, that it is a difficult matter to isolate any group for experimental purposes and determine thereby just what organs serve as the olfactory receptors. Since none of the suspected

organs presents any perceptible liquid exudation, we can only judge that those having the thinnest cuticular covering are the ones most likely to be the organs of smell. Such organs would include minute peglike, innervated hairs either standing on the surface or sunken into deep pits, thin membranous grooves surrounding elliptical or oval plates with a nerve-ending at one side, and minute disks of extremely thin cuticula over the ends of sensory cells. Organs of the first two kinds occur principally on the antennæ; the others are found on the head, the body, and the appendages, but occur particularly on the bases of the legs and the wings.

For practical experimental work on odor reactions with insects it is not necessary that the organs of smell should be identified. If insects can be shown to be definitely attracted or repelled by certain odorous substances, the facts of their olfactory powers can be ascertained. At present much experimenting is being done on the reaction of insects to odors in view of the possibility of making use of the information acquired in the control of injurious species. Certain species, it is found, can be attracted from long distances to specific odorous substances exposed in their neighborhood. In some instances the effective substances are component elements of favorite food plants, and in other cases they appear to have no relation whatever to anything in the insect's natural environment. The second fact seems surprising at first, since we have become accustomed to thinking of every character or trait of an animal as being in some way related to its mode of life. Unquestionably, a sensitivity to odors has been acquired as an "adaptive" faculty—i. e., one enabling the insect to make specifically useful reactions—but nature apparently can give no guarantee that only certain odors may be perceived or may act as stimuli to definite responses. The mechanism of reaction to odor, once acquired, may react powerfully to a new stimulus in a manner having no relation to the creature's hereditary instincts. The experimenter on insect olfactory reflexes, therefore, sometimes unexpectedly obtains his most promising results by purely random tests with chemicals from his laboratory shelves.

Concerning the sense of taste in insects, less is known than of the sense of smell. It has been shown by Will, Forel, McIndoo, Minnich, and von Frisch that insects perceive differences in solutions of various things that give us different sensations of taste. In general, the taste organs are situated in the mouth or on the feeding organs of the head, but Minnich has made some interesting experiments on butterflies showing that taste receptive organs in these insects are located on the feet. Von Frisch has recently published the results of experiments on honeybees that indicate the range of the bee's taste sensitivity for varying strengths of solutions of different things.

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REACTION TO SOUND (PHONOTROPISM)

The subject of insect hearing has not been a particularly attractive one to experimenters, because insects generally make no response to ordinary sounds. Yet the "singing" of certain male insects would seem to imply a sense of hearing in the females at least of the same species, and sense organs commonly regarded as auditory are found specially developed in the groups of singing insects. Many other insects, however, make various kinds of sounds, some of which are merely incidental to the rubbing of skeletal parts on each other, but others are produced by special rasping surfaces.

Most insects are well provided with special sense organs of the type known as "chordotonal," in the sense cells of which there are specially developed sense rods, or scolopalæ, attached by their outer ends to the surface cuticula. These organs occur at various places in the body and in the appendages. They have no external receptive parts, but in some cases an area of the body wall surrounding the point of attachment is reduced to a thin tympanumlike membrane. Tympanal chordotonal organs occur on the base of the abdomen in grasshoppers, cicadas, and certain moths, on the base of the thorax in other moths (fig. 5, *Tn*), and on the forelegs in the katydids and crickets. A special chordotonal organ known as the organ of Johnston is found in the second antennal segment of nearly all insects, the sense cells being attached to the articular membrane at the base of the movable part beyond. Chordotonal organs in general, as suggested by Eggers, may be vibration receptors, those within the body registering the vibratory motion of the muscles in action, those in the antennæ taking account of the movements of this organ. It follows, then, that a chordotonal organ attached to a membrane capable of vibrating to sound waves might become a sound receptor, or also, that a highly developed organ of Johnston, such as that of the mosquitoes and gnats, might respond to sound vibrations.

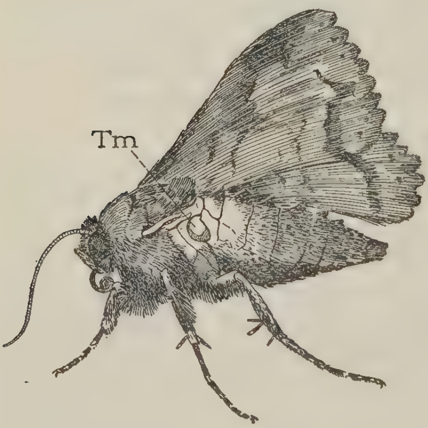

FIG. 5.—A noctuid moth with the left wings removed, showing the tympanal organ (*Tm*) on the base of the thorax

Though insects are usually unresponsive to sounds, their indifference to noise can not be taken as evidence of deafness. Several

observers have noted that the females of species in which the males produce sounds show an evident response to the chirping notes of the males. Regen, experimenting with a cricket, *Liogryllus campestris*, found that the females ceased to respond to a chirping male when the legs, bearing the tympanal organs, were removed. Peter has recorded evidence of the perception of sound by a female moth, *Endrosa ramosa.* The males of this species, he says, make a crackling sound as they fly, and when one comes near a female sitting quietly and hidden in her usual manner, the female bestirs herself with a trembling and fluttering motion as long as the male continues his sound making. By this means the males find the females and mating takes place; after mating the females no longer respond to the sounds of the males. Eggers records that noctuid moths, particularly *Agrotis pronuba*, which possess tympanal chordotonal organs on the base of the thorax, respond to loud sounds, especially to the sharp squeaking noise made by turning a glass stopper in the neck of a bottle. The moths react to the sound with a movement of fright, starting to fly or to run, but on the cessation of the sound they fall back into the position of repose. Destroying one tympanum and its chordotonal organ, Eggers says, has no effect on the reaction, but if the organs on both sides of the body are destroyed, the moths no longer react to sounds.

Some species of caterpillars have frequently been observed by entomologists to be affected by sounds, and a close study of the behavior of the caterpillar of the mourning-cloak butterfly, *Vanessa antiopa*, to sound has been made by Minnich. When normal caterpillars of this species are subjected to the tones of musical instruments and tuning forks, and to sounds produced by beating a pan, Minnich found, they react invariably by throwing the anterior third of the body upward and sideways, and even a headless body or fragment of a body will exhibit the same reflex. The sound receptive organs of these caterpillars appear to be the smaller hairs of the body surface, for when the insects were placed in a current of air, or when the hairs were wet with water, covered with flour, or removed, the sound response was eliminated. Minnich obtained reactions in normal larvæ to the tones produced by tuning forks from 1024 v./s. to 32 v./s. frequency, which is about from C'' to C_3.

It appears that the perception of sound is not a primary sense with insects, and that where an auditory sense occurs it is a secondary function of organs that were not acquired as sound receptors, one set being primarily tactile and another probably general vibration receptors, but in either case the development of an auditory function through the refinement of the organ is a logical result of the intergrading nature of the stimuli. Parker traces a gradational evolution from touch to hearing in vertebrates, the intermediate sense being

here the perception of currents in a liquid medium by the lateral line organs; and many fishes, Parker says, have the complete series of sense organs leading from touch to hearing.

REACTION TO CURRENTS (RHEOTROPISM)

Many aquatic insects are able to orient themselves according to the direction of the flow of the water, and to take consistently a position headed either upstream or downstream. Likewise, flying insects are responsive to the direction of air currents. Sensitive reactions to air movements are sometimes distinguished as anemotropism. It is not known that insects possess special rheostatic organs.

REACTION TO PRESSURE (THIGMOTROPISM)

Under this head is included general sensitivity to contact with external objects. All insects are responsive to touch, the stimulus being perceived either through the general body covering or by the motion imparted to the movable, innervated hairs of the cuticula. In general, reactions to contact are negative in that they consist of efforts to avoid the touching object; but many insects have a propensity for getting beneath things or into tight-fitting places, as into crevices in the bark of trees or under stones and boards lying on the ground, and this habit is regarded as a positive contact reflex. Sensitivity to touch is unquestionably a primitive sense. In soft-bodied insects the general surface of the skin is sensitive to pressure, but nearly all insects have specific organs of touch in the tactile hairs distributed everywhere over the body and the appendages.

Fabre believed that certain delicately lined, eversible pouches on the back of the pine processionary caterpillar of Europe are sensitive to atmospheric pressure and serve the insects as barometric organs that enable them to forecast changes in the weather.

UNKNOWN SENSORY REACTIONS

It would be impossible to include in any classification all the possible sense reactions of insects, because insects probably have many senses, such as hunger, thirst, pain, of which we know nothing. The idea of an unknown sense, "something of which we have no conception," however, though it always appeals to the imagination, has little to support it, for when it is considered that sense activities depend upon activities of the environment, an "unknown sense" remains a very improbable speculation until we discover a stimulus for it. The physicists, by means of instruments or observations of effects, have discovered no force commonly present in nature, except radioactivity, that we have not long known by means of our sense

organs. The idea of radio or X-ray communication between animals is absurd, because the energy waves involved are produced artificially only by high-power electrical apparatus.

III. INSTINCT OF INSECTS

That the complicated instincts of insects are to be analyzed into series of coordinated reflexes has been shown in a most interesting set of experiments made by Miss Isabel McCracken on the mating and egg-laying habits of the silkworm moth and by the studies of S. Kopéc on the gypsy moth.

The normal habits of the silkworm moths are so simple that the insects make excellent subjects for experimentation. The moths live for about two weeks, they take no food, and their only important instincts are those of mating and egg laying. They do not fly, they do not object to being handled, and they make no effort to escape. As soon as the adults issue from the cocoons mating takes place between the males and the females, and the latter then proceed with their egg laying, depositing during the next 12 to 72 hours, according to Miss McCracken, their total content of from 300 to 500 eggs. The eggs are not all laid at once, but in several sets of different numbers deposited at varying intervals. The egg-laying female moves the end of her body, or "ovipostor," from side to side, and the eggs are placed in regular transverse rows, being stuck to the supporting surface by a liquid cement discharged from glands opening near the orifice of the oviduct. Unmated females lay their eggs in the same manner as do the mated females, but they prolong the laying period from 6 to 10 days.

After learning the normal behavior of the silkworm moths, Miss McCracken made experiments on the insects to determine the relation between their reflexes and the individual centers of the nervous system. By cutting off the heads of both mated and unmated females, which could be done without apparent distress to the insects, it was found that the bodies alone made no spontaneous efforts at egg laying, but that they could be induced to oviposit by gentle pressure on the abdomen. When thus artificially stimulated, the headless females deposited their eggs in exactly the same way as do the complete insects, and by the influence of this stimulation, repeated from day to day, they were induced to lay the full number of eggs, after which they lived about as long as the normal moths. Headless females, moreover, could be mated with normal males, and thus made to produce fertile eggs.

Since insects have two important nerve masses in the head, the brain and the subœsophageal ganglion (figs. 2, 4, 6, *Br*, *SœGng*), Miss McCracken's experiments do not show from which head center

the stimulus of spontaneous action proceeds. The experiments made later by Kopéc on the gypsy moth are more definite in this respect. Kopéc found that if a nerve center is removed from a caterpillar, or a pair of ganglionic connective cords is cut, no regeneration of the tissues takes place and that the injured larva will transform into a moth having the same physical defect. Operations are more easily performed on the caterpillar, and the brain may be excised or its connectives severed without injury to the subœsophageal ganglion. Moths that have been reared from caterpillars in which the brain has been made functionless through the cutting of its connectives, Kopéc says, can both walk and fly and perform other normal movements, but they have no incentive to do so, and males will sit all day in cages with normal females without showing any reaction to their presence, a behavior quite different from that of males with a functional brain. A female moth deprived of her brain also shows no

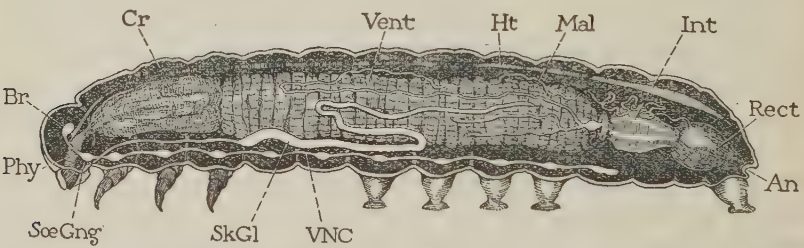

FIG. 6.—A caterpillar with the body wall removed from the left side, showing the principal internal organs (except the tracheal system) and the position of the central nervous system (*Br, SœGng, VNC*)

An, anus; ***Br***, brain; ***Cr***, crop; ***Ht***, heart; ***Int***, intestine; ***Mal***, Malpighian tubule (three on each side, but only one shown full length); ***Phy***, pharynx; ***Rect***, rectum; ***SkGl***, silk gland; ***SœGng***, subœsophageal ganglion; ***Vent***, ventriculus, or stomach; ***VNC***, ventral nerve cord

reaction to the mating instinct, though she can be mated with a normal male. Mated brainless females often lay their eggs, but they do so in an irregular, abnormal manner. From these facts Kopéc draws the conclusion that the insect brain is the nerve center from which proceeds the stimulus that activates the mating instinct, and that the brain is also the coordinating center for the process of egg laying. By other similar experiments Kopéc obtained evidence that the subœsophageal ganglion of the gypsy moth is a reflex-inhibiting center, since, after its removal, the insects become highly excitable to stimuli and their reflex movements are especially strong. The moths in Miss McCracken's experiments, therefore, were incapable of spontaneous action but were susceptible to artificial stimulation because, by the removal of the entire head, they had lost both the initiative and the inhibitory centers.

Pursuing her experiments, Miss McCracken found that the entire thorax of the silkworm moth could be removed without interference

with the egg-laying function, except in so far as the usual bodily movements were hampered by the loss of the legs; the abdomen alone, when stimulated by pressure, not only deposited the eggs, but placed them in the usual symmetrical order. An abdomen placed on its back, though, could not right itself, and in this position could not extrude the eggs from the egg duct except when the sensory hairs on the tip of the ovipositor were touched. On the slightest stimulation of these hairs, however, an egg would be ejected—a most interesting observation, showing that a local contact reflex controls the actual issuing of the eggs, a reflex that normally would assure the presence of a surface to receive the eggs, though making no distinction as to its nature.

That the head and the thorax of the moth can both be removed, and that the abdomen alone can lay eggs, if properly stimulated, make it clear that the nerve centers which operate the specific egg-laying reflexes lie within the abdomen. Through successively eliminating the action of the segmental abdominal ganglia by cutting the connectives between consecutive ganglia, Miss McCracken found that as each ganglion was separated its segment failed to take its part in the normal egg-laying movements, but that not until the outgoing nerves from the last ganglion of the series were severed did the ovipositor become inactive.

From a human standpoint it seems uncanny that an insect can be so nearly an automaton as experiments on the working of its nervous apparatus show it to be. The manner of an insect at work is enough to make the observer believe it is actuated by an almost superhuman intelligence; and yet a mere fragment of it can be independent not only of the brain, but of all the rest of the body, if only its own ganglionic center and nerves are intact. Furthermore, the entire set of reflexes that normally come into play during a complicated performance, such as that of egg laying, can take place in a perfectly ordered way in the absence of the brain and without the influence of any single coordinating center. Kopéc found that several intact ganglia were necessary for the performance of body reflexes in the caterpillar of the gypsy moth, the stimulus being sent from one ganglion to another without respect to which was first excited. In the moth, he says, there is no special coordination center for normal forward progression and for flight, the controlling power for both these reflexes being in the thoracic ganglia themselves.

The moth deprived of its brain is impassive and must be artificially stimulated to activity; the brain, therefore, appears to furnish the activating impulse for spontaneous movements. When an action is once started, however, its reflexes arising in the ventral ganglia proceed in the normal manner, or approximately so. But,

according to Kopéc, the brain furnishes, besides initiative impulses, a tonus to the entire muscular system, for all the muscles become lax when the brain is removed. Each half of the brain affects in this manner only the muscles of its own side of the body. The normal silkworm moths, Miss McCracken says, will not respond to artificial stimuli; Kopéc shows that the inhibiting centers to such stimulation lie in the subœsophageal ganglion. Thus the normal insect is compelled to act only on the stimuli received from the brain.

When it is said that the brain gives the initiative impetus to a series of instinct reflexes it is not to be understood that the stimulus arises spontaneously within the brain. The brain itself must receive a stimulus from some other source. In many cases the primary stimulus for an action initiated through the brain comes probably from a sense organ or a set of sense organs, the brain acting merely as the receiving station for an afferent sensory impulse, which is distributed from it to the ventral ganglia as an activating force that sets in motion the nervous apparatus that controls the final reflex. When the inhibitory subœsophageal ganglion is removed, external stimuli not dependent on the brain centers may directly affect the reflex centers of the ventral cord.

Primary stimuli, however, can not always be assigned to an external sensory cause; an important class of behavior phenomena in insects must be attributed to internal stimuli. The physical nature of internal stimuli in insects is not known, but the stimulating effect supposedly comes from substances produced by the metabolism of the organism, comparable to the hormones which correlate physiological processes in vertebrates. Hormones are the body messengers by which one organ arouses a second into activity when the time is ripe for combined action, or for two organs to play successive rôles in a sequence of activities. The stimulus that impels the tent caterpillars to leave their shelters at a certain time each day and go out on the branches of the tree to feed is not, most probably, a sensation of hunger but a physiological activation of the motor mechanism, effective possibly through the brain, but arising internally from some stimulus engendered by the lack of food in the crop. When the food sac is filled, another impulse sends the insects back into the tent, in the protection of which they remain during the period of digestion. (See Smithsonian Report for 1922, p. 350.) The cocoon-spinning instinct of a caterpillar becomes active at a certain stage of the insect's life, namely, that stage just preceding the series of metabolic processes which will transform the larva into a moth, and there can be little doubt that substances which may be by-products of these processes act directly or indirectly as the stimulus that initiates the spinning reflex. The special method and technique of cocoon building, however, are inheritances of each species, and, once the spinning

mechanism is set going, its orderly procedure is perhaps the result of a peculiar organization in the controlling nerve centers, though, for all that is known, each act may create the stimulus for its successor. The effects of internal stimuli are often modified by external conditions, such as temperature, humidity, and physical surroundings, but it is remarkable how the succeeding reflexes in an instinct, like the successive phases of growth and metamorphosis, will proceed against opposition from the environment and will cease to be operative only when continuance becomes impossible.

IV. INTELLIGENCE OF INSECTS

It is hard to discover the rules that govern the development of intelligence. Social animals are usually supposed to be mentally superior to individualistic creatures, and yet the higher forms of intelligence are better cultivated apart from the crowd than in close contact with it. The family home rather than the general community seems to have been the center that bred intelligence. In the evolution both of man and of the social insects home building or home life probably preceded the formation of the larger, more complex community, which when once evolved has a tendency to become regulated by customs and traditions that suppress individuality.

Animals without definite habitations may wander here and there wherever fancy takes them, or the food supply attracts them. They do not have to retrace their steps, and so they do not need to observe their course or to remember localities. But an animal with a home either for itself or for its young, which is not at the same time its prison, must know how to return after wandering abroad in search of building material or of food.

Most insects are nomadic individuals, bound by no ties to any spot. But many species have abodes of one sort or another. Some spend the day in burrows, some have a retreat in the curl of a leaf, others construct tents of silk in the branches of trees, some make nests for their young that they do not themselves inhabit, others enlarge the nest sufficiently for their own accommodation. The social bees live by nature in hollow trees or in cavities of the rocks; ants dig elaborate subterranean galleries where they live and rear their brood; the community wasps construct homes of paper which shelter the young and house the succeeding generations of the season. All such insects are able to return to their nests or dwelling places after their journeys afield wherever their duties take them. The wasps and the bees go long distances from their nests or homes, and they return with such impressive accuracy that, to the earlier naturalists, it seemed they must possess a mysterious "sense of direction." The fact, however, that these insects lose their way, as does any ordinarily endowed creature, when taken to a strange territory shows that their supposed

"homing instinct" is subject to the same limitations as common sense. Experimenters have often shown more zeal for proving the existence of such an instinct than for critically examining the value of their own observations. Thus Fabre was more impressed by the return of a few mason bees to their nests when carried blindfolded 2 or 3 miles away than he was by the loss of a much greater number and he had to look for reasons to explain why their "instinct" worked better at shorter distances.

It is now established beyond doubt that homing insects find their way back to their hives, nests, or burrows by the memory of objects with which they have become familiar. Fabre's bees simply had a wider geographical experience than he accredited them with having. The first act of the younger honeybees that have not yet ventured afield, when they join the ranks of the nectar and pollen gatherers, is to acquaint themselves with the landmarks in the neighborhood of their hive and apiary. This they do by many circling flights of observation, and it is only after they have fixed in their memories the lay of the land that they undertake alone more distant excursions. The "bee line" back to the hive is then the result of open-eyed experience and not of blind instinct. The return of insects to their homes gives the best evidence of intelligence in insects.

Some of the most conclusive and interesting experiments on the homing methods of bees are those made by Rau on bumblebees of the genus *Bremus* (*Bombus*). Rau transferred three field nests of bumblebees to cans and flower pots and took them to his house in St. Louis. After two days' feeding on honey, one colony, kept in a flower pot with a glass cover, was set out on the roof of the second story, 20 feet above the ground, where the bees could be observed from a third-story window. On all sides was the sight, unfamiliar to the bumblebees, of other house roofs like the one on which their nest was placed. In 10 minutes after the cover of the pot was moved back a little to give an exit a bee came to the opening, but, quoting Rau's account:

> She did not fly away immediately; she spent two minutes flying about the pot in zigzags, figure eights, and esses, and then repeated the same designs in larger flights around the region, often circling back past the pot in her flight. After four minutes of this wider flight she soared high and flew over the third story of the front part of the house. However, she did not dash away to the park across the street, but spent some minutes in getting her landmarks about this new portion of the roof also, and even after I thought she had gone she reappeared and once more circled about the nest. The precision of her flight of orientation is well worthy of note; first, she spent two minutes very near the nest, then four minutes in wider flight about the roof, and then a few minutes exploring the larger aspects of the roof and apparently getting them linked up with the details of her new home.

After an absence of 10 minutes the bee reappeared and flew direct to the nest, beside which had been placed a red brick and a milk

bottle for identification marks, but it took her 2 minutes to find the small aperture at the edge of the glass cover. The first bee that flew from another of Rau's nests came out in angry haste, took no note of her surroundings and failed completely in later efforts to find the nest she had left. But all bees coming out for the first time and in a peaceful state of mind, Rau says, fly deliberately about the pot and its environs in ever-enlarging circles from five to seven minutes before they venture away. Experienced travelers, however, " already familiar with the surroundings, dash off with a whiz direct to the foraging field."

In the same way bees must learn the outlying parts of the district over which they travel in their search for food. If they are taken beyond the limits of an area familiar to them, they are lost or are able to make a tardy home return only after they have found their way by chance or by random flights into known territory. Of this, again, we find convincing evidence in Rau's observations on the bumblebees of his roof apiary. In seven experiments Rau tested the ability of the insects to return to their nests after being taken in cages wrapped in paper to varying distances in neighboring parts of the city. In the first experiment, 10 bees were marked with a spot of white and taken 1½ miles east. Only 1 returned, and this 1 not until the morning of the second day. Next, 9 bees marked with red were liberated a half mile east. Three returned the same day, making the trip in 12, 47, and 225 minutes, respectively. In a third experiment, 9 bees marked yellow were set at large 1½ miles east at the same point as the first lot. None returned. Again, 6 bees marked with blue were taken half a mile to the east. Only 1 returned, after 6⅓ hours. In a fifth experiment, 13 bees, including 6 that had not been out of the hive before, were taken half a mile east. Only 2 returned, both experienced foragers. The bees in these experiments were liberated in a park which was presumably their regular visiting place. Fourteen bees were now taken one-fourth of a mile to the west, past houses and several acres of piled clay drain pipes, a territory unlikely to have been frequented by the bees, and of the 14 only 3 returned. Finally, the 3 successful bees of the second experiment were liberated one-fourth of a mile northwest in a territory offering no foraging inducements. But 1 of these returned, and after an absence of 25 hours.

In the foregoing experiments, in only 11 cases out of a possible 67 did the bees find their way back to the nest, and these 11 were successful only after varying lengths of time, probably, as Rau suggests, owing to varying luck in the trial and error method. The difference in the time of returning, Rau says—

> does away with the idea here, as it has in many other cases, that the creatures find their way home by an unknown sixth sense or by magic, for if they did so act, all would return at or about the same time.

Experiments on the solitary wasps have brought out facts of a similar nature as those ascertained concerning the homing behavior of the social bees. The females of many kinds of wasps construct earthen nests or dig burrows in the ground, in which they store paralyzed spiders, caterpillars, grasshoppers, or beetles as food for the young, an egg being placed in the nest with the prey or attached to the body of the latter. The Peckhams have recorded detailed observations on the method by which the burrowing wasps fix the locality of the nest in their minds before leaving its vicinity. The habit of some of these insects is to excavate the burrow first, then depart to search for the prey to be stored in it. Such species always make a minute survey of the nest locality by taking circuitous and zigzag flights all about the burrow entrance, often going over and over the same territory in an intricate course. And even then a returning wasp sometimes has difficulty in going at once to the exact site. If a leaf or stone lying near the burrow is changed in position, the wasp may fail entirely to locate her nest, but on the replacement of the marks the topography will again tally with her memory picture of it, and the entrance is found.

There can be no doubt, then, that the more highly organized hymenopteran insects possess memory and the intelligence at least of discrimination between sensory impressions not encountered before. This of course is only a low degree of intelligence, so low in many cases that it amounts to stupidity, but stupidity is an attribute of an intelligent being. All experimenters find that wasps and bees often will not do things most obviously to their advantage; but, as already noted, this fact indicates that they are intelligent enough to perceive alterations, though, lacking reason, they will not adapt their behavior to the change. Beekeepers, therefore, are obliged to make their apicultural practices conform with the native habits and the limitations of intelligence of the bees, for they can not educate the insects or teach them new ways. It is by no means proven that the Hymenoptera are the most intelligent of insects; they get the credit of being so principally by the lack of mental tests on other species. Abbott has made experiments on dragon-fly larvæ which show that these aquatic creatures can be trained to come to food offered them and that they learn to overcome their fear of strange surroundings.

Though the insect psychologist can not hope to find more than the rudiments of higher faculties in the mind of any insect, it is probable that a more intensive study of the insect will reveal things that will contribute to his own mental advancement.

THE EVIDENCE BEARING ON MAN'S EVOLUTION

By Aleš Hrdlička

What is the actual, precise, evidence of human evolution that science now possesses, and upon which it bases its far-reaching conclusions?

Since the Dayton trial this question has more or less been dealt with in many writings. In the United States alone more has been published on the subject since 1925 than in all the time previous, and incomparably more has been read. Yet there are many calls for further statements, for simply and comprehensively presented facts that would carry no plea, no argument, and that could safely be accepted.

To thus present the subject is not easy. Its scope is large. It involves many branches of knowledge, biological, physical, and chemical. For man possesses not merely form and his faculties, but he is at the same time a highly complex chemical and dynamic machine. To properly deal with all this would require a large treatise. Nevertheless something of an abstract of what is known in these lines is possible and may be of service.

That part of the evidence of man's evolution which is regarded as already fairly well established may be subdivided as follows:

A. THE INDIRECT EVIDENCE

1. Analogies in inorganic nature.
2. Evolution in all known organic forms.
3. Man's appearance on the earth at the right time of organic advance.

B. THE DIRECT EVIDENCE

1. Relation of various structures in the embryonic development of man to those represented by some lower vertebrates.
2. Similarities with other mammals in mode of conception, processes of development, in all vital functions, in the whole life course, in senescence when continuation of the kind is assured, and in death.
3. Physical similarities to identities in organs, limbs, and all other physical as well as microscopic parts of the human body.

4. Close similarities to identities of the chemical constituents of the human body with those of other mammals.

5. The presence in man of many vestiges of or reversions to features regularly present in lower animals.

C. THE DOCUMENTARY EVIDENCE

1. Man's cultural remains in relation to geology and paleontology.
2. His skeletal remains in the same relations.

D. THE OBSERVATIONAL EVIDENCE

1. Man's changes, physical, functional, and mental, observable scientifically at the present time, with indications for the future.

EVOLUTION UNIVERSAL

The process of evolution is now known to be a basic, universal phenomenon. Nature changes throughout, and these changes, taking place under definite laws, so long as they are constructive or progressive toward other forms, can only be called evolution. The whole cosmos, each star, each organism, and probably each particle of matter, is changing or is capable of change under proper conditions, stability being only relative. No living being, especially, it is well established, is immutable, but all are capable, within limits, of change in the form of "adaptation" to changing conditions. The possibility of adaptation is, in fact, seen to be one of the fundamental and vital properties of all organic beings. And every adaptation, every change of some consequence and duration in an organism, calls for adjustments which, if lasting, appear to bring about needed and eventually inheritable modifications in structure. To which must be added the potent influences of isolation, selection, and hybridization. The effects of all this are observable in many wild forms, and especially in the domesticated animals and in useful plants, where man has knowingly assisted nature. To exclude man and his ancestry from these basic conditions and laws would be to exclude him from the range of organisms, which seems impossible.

THE EVIDENCE OF FOSSILS

Thanks to the work of Leidy, Marsh, Cope, Osborn, and other American as well as European paleontologists, it is now possible to follow, by whole series of actual specimens, not merely structural adaptations, but progressive evolution of an increasing number of phyla of animals over great lengths of geologic time. Perhaps the best example of this is in the case of the horse, which is known in many stages, from an ancient little four-toed suggestion-of-a-horse to the fine racers and the other specialized equine forms of to-day.

But a little less known is the evolution of the camel, and much has been learned already about the dinosaurs, the proboscidea (elephants, etc.), some of the carnivores, and still other forms; and there is much evidence of similar nature on the invertebrates, such as the Ammonites and Nautilus among the Cephalopods; the Acatinelas and Partulas among the Mollusks; and also on plants (the Dicotyledons, the Conifers, etc.). Evolution, though not always of the same type or pace, and though greatly influenced by environment, is seen to be as universal a process in living beings as life itself, and no organism has ever been found that would be outside of its workings.

THE CHRONOLOGICAL FACTOR

Man's appearance on the earth at the right time of organic differentiation is one of the most important pieces of evidence as to the nature of his origin. Like the top bough of a tree, he appears only after the preceding parts or forms have reached the proper grade.

The Tertiary era, the era essentially of the evolution of mammals, is divided by geology and paleontology into four periods, each of several millions of years' duration, namely, the Eocene, Oligocene, Miocene, and Pliocene. The oldest of these, the "Dawn" period, shows only the most primitive of primates, approaching lemurs and small monkeys; the Oligocene, and especially the Miocene rocks, give remains of the true lemurs, monkeys, and eventually some anthropoid apes, such as the Dryopitheci of Europe and of the Sivaliks, or foothills of the Himalayas; while the Pliocene is the age of differentiation of the apes and anthropoids toward such forms as we know to-day, with the probable appearance, in southern Asia and also in western Europe, of some superior creatures that can only be called human precursors. After which begins the era known as Quaternary or ice age, which is characterized by repeated coolings and consequent series of ice extensions over large parts of the Northern Hemisphere, with warm periods between; and about the beginning of this age there are found to exist already at least two undoubted human precursors, if not early men, namely, the "Pithecanthropus" of what is now Java, and the "Eoanthropus," or Dawn man, of what is now southeastern England. Of these science possesses in the first case a large part of the skull, which shows a remarkable near-human brain, and in the second case a portion of a highly interesting lower jaw, not to mention other parts that are attributed to each find.

At about the same time something wholly new begins to occur on this earth. In one (at least) of the large areas that had been occupied by some of these anthropoid apes there commence to appear in the sands, clays, and gravels of those far-away periods, in company with fossilized remains of long-extinct elephants, rhinoceroses, and

other animals, flints that show intentional, objective chipping. Some creature has developed "hands," full fledged enough to do the chipping and to use the resulting tools or weapons, with mentality enough behind them to appreciate the advantage of such artifacts as well as to make them and use them for definite purposes. There is a new form of existence, a beginning of beings with enough mentality to advance to "cultural" manifestations. From which time on evidence of these new beings never lapses, but in general augments step by step, extending over many lands. The artifacts keep on developing in workmanship and variety, until, well before the middle of the ice age, they reach a status that is clearly "human." There has definitely come into being a Man.

In all this there is a logical and orderly sequence which, of necessity, must be given great weight in the studies of man's origin.

EMBRYOLOGICAL EVIDENCE

The human being begins with two minute "germ" cells, that come from the two "sexes," and that have to unite into one unit, which then divides, grows, and develops in most intricate ways, all precisely as in the case of any other vertebrate. This beginning of the new being, and the following stages of embryonal development, constitute an array of conditions and processes so minute, and so important, and so thoroughly regulated, that they could never be duplicated accidentally. To the student with the microscope the organic unity of man with the rest of the living beings, and especially with the rest of the mammals, is indeed a profound fact, a fact so plain and complete and great that to the scientist it alone is wholly sufficient for a conviction of unity. Even heredity, that vastly complex endowment of every organism, is now known to be carried by like clusters of molecules, known as "chromosomes" and "genes," in each germ cell, human or animal.

In addition, the human embryo shows at various stages traces of prehuman characteristics that disappear or are reduced to rudimentary condition in the course of subsequent development. These matters are too technical for a general discussion, but features that may be mentioned are the initial primitiveness of the neck, hands, and feet; the rudimentary tail which persists in the human embryo up to and even over the ninth week of prenatal age; the early hair covering the body and face; the presence of plain traces of the intermaxillary bone; the at first birdlike, entirely smooth brain. These and other similar features, taken together, are so impressive that the human embryonal period has been called the period of "recapitulation" of evolution.

PHYSICAL, FUNCTIONAL, AND CHEMICAL SIMILARITIES

The fully developed human body on being studied and analyzed, has been found, organ for organ, function for function, and chemical constituent for chemical constituent, so near to that of other mammals and especially the anthropoid apes, that the fundamental unity of all seems clearly apparent. Small or great, simple or complex, there is nothing in man a counterpart of which, though modified more or less according to the needs of the species, is not found also in other mammals. The differences are seen to be only in secondary characters, such as size or exact shape of the parts, acuity or duration of a function, a little plus or minus chemically.

The above appears true even to the brain, which while relatively larger and more complex and, in some directions, immensely more efficient in man, is still in all essentials, even to the kinds and arrangement of brain cells and localization of nervous centers, much like the brain of any of the higher anthropoid apes and other mammals. The brain subdivisions into cerebrum, cerebellum, medulla, and pons; the subdivision of the brain matter into the gray and white substance; the special brain "nuclei" and the cavities; and even the principal convolutions and furrows of the cortex, are substantially the same in man and the Primates, as well as many other mammals. The most striking, however, is the same location in all these forms, from the dog and the ape to man, of the various important functional areas, such as that of sight, hearing, association, etc., and of the series of clusters of cortical brain cells which control the action of various sets of muscles. The location of these centers has been learned through electrical experiments on the brains of the dog, the chimpanzee, and other animals, and then it was found that the same number, order, and location of these centers is present in man. This knowledge is constantly being made use of in diagnosing the location of lesions or tumors in the human brain and for successful surgical operations on the organ.

From the physiological point of view, man appears animal-like in the entirety. All his functions, assimilation, metabolism, elimination; the circulation and oxidation of his "blood," with the blood composition and its qualities; the senses; the sexual functions; the great function of the whole life cycle itself—all appear as true counterparts and mere variants of what is found in the rest of the higher animal forms.

As to the related chemical similarities between man and other mammals, these are so generally and so well established that extracts of animal blood and animal glands, which mean nothing but very complex chemical compounds, are used on a great scale for protective vaccination of, or to supply defects of similar substances in man.

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Thus, the pepsin of the pig, the thyroid of the sheep, the pancreatic extract (insulin) from these or other mammals, the extracts of suprarenals and even those of the sex glands of apes and other animals, with the immunizing sera from the horse, calf, rabbit, etc., are constantly being utilized to supply the want of such substances in our body and thus to prevent or cure our diseases. The common cod-liver oil is merely a carrier of certain organic chemical substances that are lacking for a time being or are being produced in insufficient quantities in some human children. Comparative pathology gives many further illustrations in this connection.

Even in the lower-order mental traits, man can not be said to be apart from the rest of the living beings. He, too, is still subject to different "instincts," fears, desires, "animal passions," etc., which he inherited from far back and the counterparts of which may readily be recognized in other living forms about him. In the higher mental manifestations only, in self-consciousness, rational self-control, thinking, planning, idealism, intellectual feelings and pursuits, is he, in degree at least, high above all other life. It is his intellectual entity and potentiality, this something surpassing that constitutes his "soul," that places him above the rest of creation.

VESTIGES AND REVERSIONS

Another line of strong evidence of man's basic unity with the rest of the organic beings, and of his ascent from the same, is plainly furnished by the many vestiges he carries of his ancestral forms, and by the occasional reversions to prehuman structures, or behavior.

In instances the human mother will bear from two to six children at a birth; and several hundred of instances are recorded in medical literature of women and even men who had supernumerary breasts or nipples, located more or less as they are in other mammals.

The human baby will cling strongly to a rod, branch, beard, or hair; and it shows various characteristics in its actions, physical and functional, that have prehuman connections (see literature on Atavism). There are young children, Indian, white, and negro, running habitually and effectively on all fours (see Am. J. Phys. Anthrop., 1927, No. 3, 1928, Nos. 1 and 2). There are children with "dents du chien" (dog-teeth), which consist of very prominent canines; and the human canines in general are apparently but the reduced weapons of other mammals.

The "Darwin's tubercle" occasionally found on man's ear, or the absence of the ear lobule; the arrangement of the hair over the limbs; the occasional webbing of the 2 and 3 toes; an extra lobe at the lower end of the right lung, or the division of the left lobe of the liver;

the remnants of the platysma (muscle of the skin) and of the ear muscles; occasional forms of the incisor and molar teeth; supernumerary incisors (many mammals have more than four), and fourth molars; the coccyx; the supracondyloid process of the humerus; and now and then certain fissures of the brain—appear all to be vestiges of prehuman conditions and features testifying in their way to man's ascent from lower organisms.

REMAINS OF THE EARLY MAN

The actual documentary evidence of man's origin and gradual rise is already very respectable and is steadily growing.

When Darwin wrote his epoch-making books on the Origin of Species (1859) and Descent of Man (1871), man's prehistory was barely beginning to be known.

Since then, the cultural remains of early man, consisting of his stone implements, and of the bones of extinct animals on which he left his traces, reach literally into millions; and skeletal remains of ancient man himself have reached such numbers that but a few students are able to master the whole riches.

The cultural objects occur in quantities in ancient caves, deposits, and river terraces, especially in western and central Europe, but also to some extent in north Africa and Asia Minor, with possible extension southward and eastward from this territory. The cave of San Brelade, on the island of Jersey, has already yielded to Professor Marett and co-workers approximately 20,000 stone objects showing the work of man; the site of La Quina, in southern France, gave Henri Martin over 100,000 specimens, many of which are whole implements; the Viestonice site in Moravia, of which only a small part has been excavated thus far, has already given to Absolon over 300,000 objects showing the work of early man; and the Musêe de St. Germain, near Paris, the Institute de Paléontologie at Paris, the National and Cinquantenaire Museums of Brussels, the British Museum, the Territorial Museum at Brno, and many other institutions, in Spain, Germany, and elsewhere, possess collectively vast quantities of such remains, with more coming to light every day.

These stone implements and other cultural objects are found associated with the bones of various extinct animals, which help to date them. These animals range from ancient elephants, rhinoceroses, lions, leopards, hyenas, etc., to the mammoth, cave bear, reindeer, extinct horses and bisons. They show warm and cold periods, corresponding with the subdivisions of the ice age. And the stone objects show definite phases or fashions of workmanship which, together with the criteria of age, enable the student to classify human pre-

history into a number of cultural periods. The main of these, proceeding from the past toward our time, are:

The Old Stone Age (Paleolithic).

The pre-Chellean and Chellean.
The Acheulian.
The Mousterian (or Neanderthal) {lower. middle. upper.
The Aurignacian {lower. middle. upper.
The Solutrean, the Magdalenian, and the Azilian.

The New Stone Age (or Neolithic).

Here is a great mass of evidence that may easily be seen in European and even American museums, or in the field where, especially in France, under Government regulations and guardianship, whole sections of the implement-bearing strata are left as archeological monuments. Moreover, the old implements, animal bones, etc., may readily be collected first hand. (Consult on this subject Osborn's Men of the Old Stone Age; MacCurdy's Human Origins; and Burkitt's Prehistory.)

However, there is much more than this. In addition to the innumerable cultural remains of early man, the European scientific institutions now possess also the skull fragments to complete skeletons of over 100 prehistoric men and women that may safely be dated at more than 20,000 years of age. These precious documents are held as national treasures in France, Belgium, England, Germany, Czechoslovakia, Croatia, and other countries. They range from a portion of a lower jaw, with perhaps a few pieces of the skull, as in the case of the already mentioned Piltdown find in England, to most of the parts of 18 skeletons discovered at Předmost, Moravia. They come from ancient gravels, sands, or loess, from old caves and rock shelters, and even from deep in hard stone, as in the quarries of Ehringsdorf, near Weimar, in Germany. They are associated with and in instances overlaid by the bones of ancient mammals. They show various grades and forms of petrifaction; and, in general, the older they are the more primitive is their form and the farther away they are from the modern human. (See writer's Most Ancient Skeletal Remains of Man, 2d ed., Publ. 2300, Smithsonian Inst.)

Here is before us a most weighty evidence of human evolution, and in a large measure already an actual illustration of the process. When an observer regards such specimens as the Piltdown, the Heidelberg, the Krapina or the Ehringsdorf jaws, the Neanderthal, the La Chapelle, the Gibraltar, the Spy, la Ferrasie, the Galilee, and

the Rhodesian skulls, and even some of the later crania and skeletons, he sees forms that he could hardly believe were truly human; yet these skulls show already fairly large and distinctly human if not superior brains, and the teeth, with the bones of the body, even though more primitive, are nevertheless already clearly those of Man.

The originals of these precious skeletal remains are scattered over Europe, but the main part of them may be seen collectively in perfect replicas in two of our foremost American institutions, namely, the National Museum at Washington and the American Museum of Natural History in New York, while more limited series are possessed by several larger American museums that include the subject of anthropology.

To this invaluable material further originals are being added every year through new discoveries, and, as conditions in Europe for scientific research grow more propitious, it is safe to expect an ever-increasing flow of accessions in this direction. Since 1920 a selection of American college men and women actively participate abroad under the American School for Prehistoric Research in the studies and excavations for early man, with the object of bringing back first-hand knowledge and experience in this field, and they have already discovered and brought back to this country some rare ancient specimens.

THE CURRENT EVIDENCE OF MAN'S EVOLUTION

This important phase of the subject has so far been dealt with but little by the writers on human evolution, due mostly, perhaps, to a lack of perspective.

There are thinkers, occasionally even among the foremost men of science, who regard organic human evolution as practically at an end. They observe that the all-potent natural factors of evolution, such as isolation, natural selection, and the influence of the environment, have nearly ceased to act on man. Man in a large measure has neutralized these factors through ever-freer communication and self-protection, and through many artificialities, in the way of housing, clothing, heat, food, and other agencies.

Every generation, every year in fact, man is making himself more and more independent of the very influences that forced him on in the past; and as there can be expected no changes in nature to which man could not more or less readily adapt himself, it is easy to conceive that he has reached, or nearly so, a sort of equilibrium with nature and hence the end of his personal changes. The future evolution of man, in the opinion of the students who hold these notions, and the foremost representative of which in this country is perhaps Edwin Grant Conklin, will be of social rather than of organic order.

These views fail, however, because of two vital conditions. The one is that according to all tests man is still as plastic—that is, impressionable and changeable—as he ever was, if not more so; while the second is that man is developing new and powerful evolutionary factors of his own.

That man is still plastic—reactive to all changed or new influences by proper accommodation—is plain enough, especially to the medical observer and the anthropologist. In pigmentation, in stature or strength, in form and size of the teeth and jaws, in the dimensions of all other organs, including the brain, and in his functional qualities and effectiveness, including those of the mental powers, he is seen to respond to changing conditions; and these reactions are observed to be the more prompt and effective the higher in civilization and refinement is the individual. It may be stated, and that as an organic law, that every reaction, whether in the direction of more or of less, unless artificially counteracted, leads, if repeated often enough and within the healthy limits, to an organic habit and organic modification. And such habits in the course of time lead, in some way that as yet is not fully understood, to more or less hereditary traits—which are items of evolution or devolution.

Acquired characteristics, the influence of which does not reach deep enough to the trophic centers of the brain or nervous system and the germ cells, are as a rule not inherited. But there are many functional acquirements that evidently in time do reach these depths, as a result of which they tend to become fixed and hereditary in families or even in large groups of men.

Studies on the descendants of the older American families have shown conclusively that stature in these families has materially increased since their coming to this country (see Old Americans, 8°, Balt., 1925).

The form of the head has been slowly changing within the last thousand years, as shown by the works of Matiegka, von Luschan, Fleure, and others, in Bohemia, Austria, England, and Germany.

Changes in pigmentation have greatly affected, and have become more or less fixed in, the Aryan population of India since their coming to that country; while others of opposite nature, *i. e.*, in the direction of lightening, may now, according to various indications, be slowly proceeding, as in the Eskimo, the civilized American Indian, and the North American Negro.

The civilized white male shows everywhere an increasing weakness of the hair, and early baldness is already a hereditary trait in the males of many otherwise normal families.

There is perceptible in the civilized man of all races a progressive refinement of the physiognomy, with diminution of the protrusion

and size of the cheek bones, lessening of the size and massiveness of the jaws and teeth, and more generalized beauty. These features, or a tendency toward them, are being passed on to the progeny.

The teeth of the more highly civilized white man, through less use, have not only become smaller, but especially less resistant, and some of them, at least, tend to a tardier eruption, causing many difficulties and irregularities. Other changes in size or shape have, under the influence of other factors, taken place in the teeth in various groups of man. All these changes have become more or less hereditary.

The higher civilized man, besides this, has, it seems certain, advanced in the lines of human endurance, due to the stresses of civilization and the calls for endurance. He may not have the more automatic strength of some primitive people, but his eyes, ears, body, and, above all, the brain are evidently capable of greater conscious exertions, and endure longer. The last war taught much in this direction, and on every side may be seen the great endurance of the financier, the industrial leader, the intellectual worker. The amount of labor they are able to perform, the strain endured by eyes, all the senses, and, above all, the intellectual powers, are at times astounding. Nothing of that nature is evident in the old times except in rare individual mental giants. Qualities appear now manifested by multitudes which in the past were barely manifested by individuals.

Therefore, it seems safe to say that the human frame and, above all, the human brain, are still quite plastic and respond, by strengthening or weakening, to all sorts of influences.

On the other hand, the natural laws conditioning evolution are still acting, except for man's interference. Natural selection still eliminates the incurable and unfit, and gives the leadership in progress to the strong and fittest. Fault, weakness, transgression of all nature's law, must still inexorably be paid for by the defective or culpable. Nevertheless, the evolution of man to-day is being more and more directed or led by forces different from those in the past. Even though nature is still acting, it is being left behind by the human factors, by man himself. Man is beginning to materially supplement and partly to replace nature in the process of his own evolution, as he has in the case of domesticated animals, and is advancing upon nature.

He is using more and more, and ever more effectively, self-protection. Survival of the fittest does not apply to man as it once did. Natural selection has been modified, so that it means no more the survival of the fittest alone, but preservation as well of all who can be preserved. Fear is not seldom expressed that this preservation of the weaker will have a deleterious effect upon man's future; but

fortunately these fears are not well grounded. Many of those who are preserved are not unfit except in some one particular, as in a predisposition to or lack of immunity toward one disease, such as diphtheria or consumption. And with the really weaker who are preserved there enters into play a most beneficial factor, the old but ever potent *vis medicatrix naturæ*, which heals and strengthens.

Were it not for this important factor, whole groups of mankind would probably have perished in the past, as after the epidemic of syphilis in Europe in the sixteenth century. Many families have certain infections or weaknesses, but we see that in the majority of cases the family does not perish; instead there is a gradual restitution, and in a few generations through this and strengthening by marriage with healthy stock, the bad effects may disappear entirely.

Through ever more effective self-protection man counteracts the hard mastership of nature. He is replacing nature's tutelage by more and more correct self-training and education. Children, on the whole, are ever more carefully trained, and adolescence is turned more effectively in a fit direction—brief periods of demoralization, such as that of the present postwar period, notwithstanding.

The white child and adolescent of to-day lead, on the average, a more normal and healthy life than did the child and adolescent of any time in the past. Growing-up girls and boys are taught that it is not desirable to mate with the sick or the mentally unfit. More rational and scientific care is taken of the defectives, in this way eliminating one of the most serious disgenic features of the past. School and college life are being regulated ever more rationally. Hours of labor are reduced to avoid physical and mental exhaustion, and harmful labor of children is largely done away with. In many factories the workmen are being taken care of as valuable assets of the concern. Men in mass, soldiers and employees, are being restored to health, strengthened, and instructed in hygiene. All this together is certain to have a large and wholesome evolutionary influence upon the future generations.

New ambitions and necessities, new inventions, and especially new and intense competitions, are acting powerfully upon present man in highly civilized societies—much more so than they have ever acted in the past. When we weigh the effects of the automobile, movies, radio, the daily newspaper, etc.; when we contemplate what groups of competing business men or any other men go through; when we feel man's utmost efforts in all directions—we can not but recognize that things very potent are developing in human relations, which must have an effect upon man's further evolution in a mental as well as in a physical direction.

About the greatest factors of contemporaneous and future progressive human evolution, however, are the thirst and striving for the

better, for something ever higher and better in every line. This means a desire and striving for ever greater strength, beauty, bodily and mental effectiveness, mental freedom, ability, power, and true happiness. The more man is developed intellectually the more there is of this striving for a higher state and happiness and progress and intellectual freedom.

This great factor was not so manifest in times past. A man then was too often satisfied to serve another provided he had enough food and a little leisure. This agency has already had, and is bound to have in the future, a very potential effect on man's evolution. Notwithstanding the difficulties in the way it is ever refining man's mental actions, making more out of humankind in every way. And with it will proceed an ever more intelligent and discriminating sexual selection, which has been in the past, and promises increasingly to be in the future, a potent aid to favorable evolution.

These factors and agencies, and still others, are plainly in action on the civilized man to-day; are largely taking the place of the older natural agencies which gradually have been losing their power on the direction of man's evolution. They may prove equally, and in some respects even more, effective. Their promise is a gradual orthogenesis, or evolution of man in the right direction, physically, as far as this may still be possible, but above all intellectually; evolution toward beings ever freer from imperfections and limitations; an evolution in general ever more guided and safeguard through increase of knowledge.

But this highly promising road is not without many obstacles and even serious dangers. A sober view of the human future sees, indeed, further evolution, but evolution amid and through difficulties. Some of these may here be enumerated:

Modern diseases.—There is no record in the distant past of tuberculosis, and it was very scarce even in the time of dynastic Egypt. There is little if any evidence of cancer until fairly recent times, and none of rickets. As animals in confinement develop diseases unknown in freedom, so with men; domesticity brings new infirmities. These are often now connected with overexertion, where man is forced beyond his powers and so falls more often a victim to diabetes, heart and lung trouble, nervous disorders, insanity. They are, however, also connected with man's lengthening life period. Medicine is trying to overcome these, but so far not very successfully; they may constitute serious impediments to human progress for the future. There is, however, no perceptible need of apprehension that diseases of the civilized man—barring, perhaps, the lighter psychoses—will increase or that new and uncontrollable scourges may originate.

Great wars.—These constitute an obstacle of man's own making. Great wars are unquestionably deleterious, and the disgenic influences of the last war will be felt for still some time to come. The underlying cause of wars, however, is increasing density of population, just as it was in the old invasions; and the remedy for wars lies essentially in that direction. Unless some as yet unknown agency of nature develops, before long one of the main problems of the world will be to control its population.

Idleness, *luxury*, and *demoralization*, collectively, are perhaps even more deleterious than war. It is a truism that as soon as any being, or any group—be this a family or a nation, ceases strenuous endeavor and yields to comfort and indolence, or falls to demoralization, he or it commences to retrograde and lose in physical and mental standards.

Excesses and *strains*, due to the very exacting and irregular modern life, produce weaknesses that call for stimulation by coffee, nicotine, alcohol, or drugs. Some excesses and strains were, of course, always present and always disgenic; but they are growing much more common and new ones are being added. Repeated excesses lead to overstrains, and result not only in the diminished potentiality of the individual in every way, but also in poor progeny. They lead to the generation or retention in the system of poisons that may and often do affect the germ plasm. The child of an overstrained or neurasthenic individual can not be absolutely healthy or fully efficient.

Poisons in chemical and manufacturing plants must also be considered. His multiplied and widely differentiated occupations and even his needs and pleasures bring man into contact with many new poisons. Such poisons, too, acting deeply, must often affect the germ plasm. Man is using his growing knowledge to counteract these poisons, but this knowledge is not yet sufficient.

Then there is *mechanization.* It is estimated that approximately 8,000,000 men, women, and children in this country alone are for seven to nine hours a day doing automatic work that calls for little or no mental exercise. This in the course of time can hardly fail to have a disgenic influence upon the mental, if not also upon the physical, life of many an individual, and in the long run can not but be harmful to the race. The automatic work of the day is often compensated for by harmful excitement or excess afterwards—also a disgenic factor.

Finally may be mentioned misapplied *birth restriction.* The principle of birth restriction is sound and necessary, but the misfortune is that the very people, the morons and defectives, who should practice birth restraint most, do so least, while those who ought not to practice it, the intelligent and well to do, are those who put it

most often into effect. This danger can be counteracted by the better bringing up of the youth; by rational regulations as to the defectives; and by such measures as the furnishing, together with and as a part of the marriage license, to every marrying couple a treatise of a high order on health, eugenics, and happiness in the family.

Thus it is seen that on one hand man is supplementing nature and helping himself on his way, making errors only through ignorance or abnormality, and with an advance of dependable knowledge, is becoming more and more a factor in his own evolution. On the other hand, there are still many agencies that are retarding and may at times even threaten his progress. These may gradually be neutralized or done away with. Largely the question is again one of knowledge, which, translated into practice, means more research, instruction, real enlightenment.

As true knowledge will advance, men may safely be expected to proceed gradually more and more toward rational and scientific self-regulation and self-direction; for that will, according to indications, be the road toward happiness and progress in the right line.

CONCLUDING REMARKS

That, briefly, is the scope of the scientific evidence of man's evolution, and of its indications for the future. A true appreciation of the subject carries with it, to the scientist, a sense of deep gratification. To be the chief product of a great life-tide of millions of years' duration, seems to man an achievement of the highest order, and furnishes at the same time a substantiation of his supreme position in the organic world.

If ages have labored and built to produce Man, an appreciation of the fact is bound to be full of proud consciousness and deep responsibility. With the knowledge of his past, furthermore, and with that of his present, man can well feel that ages of further development are still ahead of him, so that he may eventually reach the highest legitimate aspirations.

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THE ORIGINS OF THE CHINESE CIVILIZATIONS[1]

By Henri Maspero

It is commonly stated that Chinese civilization had its birthplace in the northwest of China, in what are to-day central Shensi and southwestern Shansi Provinces. There, on the banks of the Yellow River and along the lower Wei and Fên, its tributaries, between the Ch'in-ling Range on the south and the foothills bordering the Ordos Plateau on the north, it had its cradle. Thence the hardy pioneers, descending the Yellow River, set out to conquer and colonize the great eastern plain, over which now extend the Provinces of Chihli, Shantung, and Kiangsu, as well as the northern and western portions of Honan and the north of Anhui. This hypothesis, which has nothing to justify it and which everything seems to contradict, has received the sanction of long acceptance and has had the good fortune to be constantly reenforced by the successive preconceptions of various authors who during the past three-quarters of a century have concerned themselves with Chinese origins.

The first and best translator of the "Chinese Classics," the Rev. James Legge, carried his theory back to the Tower of Babel:

> The [Chinese] tribe * * * began to move eastward, from the regions between the Black and Caspian Seas, not long after the confusion of tongues. Going on, between the Altaic range of mountains on the north and the Tauric Range, with its continuations, on the south, but keeping to the sunny and more attractive south as much as it could, the tribe found itself, at the time I have mentioned [about 2000 B. C.], between 40° and 45° N. L., moving parallel with the Yellow River in the most northern portion of its course. It determined to follow the stream, turned south with it, and moved along its eastern bank * * * till it was stopped by the river * * * turning again toward the east. Thus the present Shan-se was the cradle of the Chinese Empire.[2]

On his part Richthofen, persuaded that the three great civilizing peoples of the Old World, the Indo-Europeans, the Semites, and the

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[1] Translated by permission from Annales de Géographie, No. 194, XXXV[e] Année, Mar. 15, 1926. Translation by C. W. Bishop. (The Wade System of transliteration of Chinese names has been employed in this article because of its being based upon English phonetic values.)

[2] *Legge*: Shoo King, Prolegomena, p. 189. In his Ch'un-ts'ew, Prolegomena, p. 134, he puts the first settlement of the Chinese in "the southwestern parts of the present Shan-se, and perhaps also on the other side of the stream."

Chinese, must have had a common abode in central Asia about the Pamir Plateau, the former to the west of the Tarim Basin, the latter to the east, in the Yarkand and Khotan region, brings the Chinese stage by stage on their eastward way, first into modern Kansu Province, and thence, at an "uncertain epoch" but prior to 3000 B. C., into the Wei Valley in Shensi.[3] From this region, which for him, too, was the cradle of Chinese civilization, a new theory, based upon his own personal interpretation of the Yü Kung or "Tribute of Yü," a brief treatise forming a chapter of one of the "Classics," the Shu Ching, enabled him to follow their further movements. According to him, we have in this work a description of the routes followed by the Chinese from their primitive abode, eastward to Shensi, along the lower Yellow River, and southward as far as the Yangtse.[4] This interpretation, however, although ingenious, is too arbitrary to have found acceptance.

About the same time Schlegel,[5] led through false etymologies into regarding the "primitive roots" of Chinese and Sanskrit as identical, naturally brought the Chinese along a similar road, from the country common to them and to the Indo-Europeans in primitive times, down the Yellow River to their present domain.

Terrien de Lacouperie believed that he had proved the identity of ancient Chinese writing with cuneiform, and further of the names of Shên-nung and Huang-ti, two mythical Chinese emperors ascribed to the thirtieth century or thereabouts, and those of Sargon, king of Agade in Babylonia, and of Kudur Nakhkhunte, king of Susa. For him the Chinese, whom he calls the "Bak tribes," taking for an ethnic name the expression "the hundred families"[6] by which they often designate themselves, were a tribe of emigrants who set out from the region west of the Hindu Kush and southeast of the Caspian, in the vicinity of Elam (Susiana). He follows them clear across Asia, regarding all the place names containing the syllable "bak" as traces of their passage, e. g., Bactriana, Bagdad, Bagistan, etc. He makes them cross the Pamir and descend upon Kashgar and Khotan, finally bringing them to the banks of the Yellow River and the Lo and Wei, in Shensi; he even claimed to be able to fix the exact date of this migration, which he assigned to the years 2285–2282 B. C.[7]

Thus, whatever their opinion regarding the origin of the Chinese, these writers all agree in bringing them into China from the north-

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[3] Richthofen; China I, pp. 414, 415, and map 3.

[4] Richthofen, op, cit., I, pp. 340–342 and map 5.

[5] Schlegel; Sinico-Aryaca ou recherches sur les racines primitives dans les langues chinoise et aryenne. Batavia, 1872.

[6] In Chinese, "pai-hsing"; the ancient pronunciation of the word "pai," meaning "hundred," was incorrectly restored by Terrien de Lacouperie as "bak."

[7] Terrien de Lacouperie; Western Origin of the Chinese Civilization. London, 1894, pp. 26, 27, 302, 305, 309, 321, etc.

west and placing their first settlement in the Valley of the Wei. They believed themselves justified in doing so by what they, following the Chinese themselves, regarded as the authentic history of primitive China. The Emperor Yao, whom the official chronology places in the twenty-fourth century B. C., was believed to have had his capital at P'ing-yang,[8] on the Fên, in Shansi. His successor Shun is said to have established his own farther south, near P'u-chou, in the same province. That of his successor Yü, in the twenty-second century, had been situated, so tradition alleged, not far away, at An-yi; but the fief of Hsia, which he had held prior to his accession, was near the present city of K'ai-fêng, in the eastern plain, about the region where his descendants, the emperors of the Hsia dynasty, set up their successive capitals, in Chihli and Shantung Provinces. Thus the accession of this dynasty at first sight bears the look of having marked a fresh step in advance on the part of the Chinese conquerors, at first confined to the upper Yellow River but passing thence into the plain through which flows the lower portion of its course.

This entire scheme, however, is founded upon a most violent distortion of the traditional Chinese history. In the first place, these changes of capital have never been regarded by Chinese historians as indicative of a migration or a conquest; any such interpretation is only a forced one on the part of European scholars anxious to find confirmation for their preconceived opinions. Moreover, even this apparent justification can be obtained only by establishing an arbitrary division in Chinese official history, according to which the reign of the Emperor Yao is selected to mark the beginning of what is claimed as authentic history, while everything earlier is thrust back into the realm of legend. In point of fact, for the period before this sovereign, tradition locates all the oldest capitals in the eastern plain, in southern Chihli, in Shantung, and in Honan. That of Ti-k'ou, the father and predecessor of Yao, is said to have been near P'o, in Honan, and that of Chuan-hsü, predecessor of Ti-k'ou and grandfather of Yü, at P'u-yang, in Chihli. As for Huang-ti, grandfather of Chuan-hsü and great-grandfather of Ti-k'ou, some declare that he never had a fixed capital, while others make him reside at Hsin-chêng, in Honan. Before him again, the capital of Shên-nung is placed at Ch'ü-fu, in Shantung, and that of Fu-hsi, the first emperor according to the official history, at Ch'ên, in Honan.

All this is of little importance. The official history of Chinese antiquity is in fact only a collection of legends; the reigns of Shên-

[8] The names of a large number of Chinese prefectures and subprefectures have been altered since the administrative reform of 1914; but since the names in use prior to this reform are the only ones to be found on European maps I have retained them in this article.

nung, of Huang-ti, of Yü, are all three only euhemerized versions of the same mythos, that of a hero sent from heaven to establish order in a world covered from its beginning with water;[9] of Shun all that we are told reduces itself to a folklore tale, that of the stepson persecuted by his stepmother and her sons but triumphing over all their snares and finally marrying the daughters of the king. As for Yao, he is but a name, to which not even a personal legend has been attached. Of the Hsia dynasty, which commences with Yü, nothing is known save certain euhemerized mythological tales about the founder Yü and his son Ch'i, and also about another hero, a sort of Chinese Heracles, Yi the Great Archer, a mighty destroyer of monsters, who has become artificially connected with Yü. It is only toward the close of the Yin dynasty that real history commences, in the persons of its last kings, who are mentioned in certain recently discovered inscriptions on tortoise shell. These, however, cover only a short period; thus documents cease again almost immediately, not to recommence in continuous fashion until the last years of the eighth century B. C.

It was therefore quite mistakenly that confirmation was sought in the ancient history of China for theories placing the cradle of Chinese civilization in central Shensi and southwestern Shansi. Conrady,[10] impressed with the fragility of this hypothesis, proposes to seek the place of origin of Chinese civilization in southern Shansi and northern Honan, on both banks of the Yellow River; it would be, according to him, from this region that the Chinese colonists swarmed, some eastward into the maritime plain, others westward into the Valley of the Wei, while others again went south into the basin of the Yangtse. But the area selected by Conrady is singularly inappropriate for the rôle which he assigns to it. It is not by chance that during 3,000 years of history Shansi and Honan have always formed separate States or Provinces; all the country north of the Chung-t'iao Mountains in Shansi faces toward the valley of the Fên and the adjoining alluvial basins; while the northern portion of Honan, on the contrary, looks toward the Yellow River. These mountains mark a clear-cut line of division, and it is hard to see here a single center of culture diffusion. This difficulty is only enhanced when we study the relative positions of the Chinese and barbarian populations in these Provinces in ancient times.

At the opening of the historical period, toward the beginning of the eighth century, the Chinese were far from being the only inhabi-

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[9] Henri Maspero; Légendes mythologiques dans le Chou-king. Journal asiatique, CII, 1924, p. 47 et seq.

[10] Conrady; China, 482 (Pflugk-Harttung's Weltgeschichte). The same theory has recently been maintained by Doctor Erkes, China, 28. Doctor Forke, Die Völker Chinas, 40, leaves the question open and contents himself with saying that "the oldest seat of the Chinese was in the vicinity of the Yellow River, in the Provinces of Chihli, Shansi, Shensi, Honan, and Shantung."

tants of the Yellow River Basin. Only the arable irrigated plains belonged to them, while all the uplands were in the hands of the barbarians. The terraced plateaux of Shansi constituted the realm of the Ti. To the south, the six tribes of the Red Ti, the last of which was only subdued in 593 B. C., occupied all the *massif* dominating the Yellow River on the north, from its eastward bend, where it leaves Shensi, as far as the upland valleys of the Chʻin and the two Chang. The Kao-lo, the southernmost tribe, inhabited the Chung-tʻiao Mountains, above the present subprefecture of Yuan-chʻiu. Farther east, on the upper waters of the Chʻin and the Chang, were the Lu-shih and the Liu-yü, whose names survive in those of the modern districts of Lu-an and Tun-liu. To the north lived the Chiang-kao-ju and the To-chʻên, the exact habitat of the latter being unknown. Finally the Chia-shih, the most eastern, occupied the slopes of the Tʻai-hêng Mountains, descending even to the banks of the Yellow River near Chʻi-chʻo. Still farther north, in the Wu-tʻai Range dwelt the three tribes of the White Ti; the Fei and the Kou were to the east, in the vicinity of Hsin-lo, while to the west were the Hsien-yü of the Chung Shan, who succeeded in maintaining their independence until 296 B. C. Finally all the west center of Shansi as far as the Yellow River was peopled by the Western Ti, who, less well protected by the nature of their country, had been subdued by the middle of the seventh century. These people were in contact with the nomads of the north, who from very ancient times had led a pastoral life on the steppes of the Mongolian Plateau. These were, on the west the San Hu or "Three Hu," two tribes of Huns, the Liu-fan around Kʻo-lan and the Tai-lin around So-pʻing, in the extreme north of Shansi, on the Yellow River near its bend toward the south, about where, in the beginning of the Christian era, the Huns held their great politico-religious autumn assembly; and on the east, near the sea, certain tribes of Manchus, the Eastern Jung, also called the Eastern Hu or the Wu-chung; and still farther toward the northeast a people called the Mo, who had neither towns, palaces, houses, nor ancestral temples, and who cultivated millet alone.

To the south and west of the Yellow River the Jung barbarians occupied all the uplands surrounding the Valley of the Wei. In the mountains to the north as far as the Ordos Plateau, and west to the sources of the Wei, the Ching, and the Lo, were the Chʻüan Jung, the Jung of Ti-huan, the Mien-chou, the Wu-shih, and the Yi-chʻiu; the last named resisted the Chinese for centuries and did not lose their independence until 315 B. C. Some tribes still existed out in the midst of the plain and even as far as the banks of the Yellow River, forming isolated groups among the Chinese. Of these were

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the Jung of the Tʻang-shê north of the Wei, between Ssŭ-yuan and Hsing-pʻing; the Chʻüan Jung between the mouths of the Wei and of the Lo; the Ta-li of Tʻung-chou, subdued only in 461; the Pʻêng-hsi of Po-shui on the banks of the Lo; and the Li Jung in the foothills of the Hua Shan, who on the north reached the banks of the Wei near the modern Wei-nan, a vestige of the time when not only the mountains but the plain also formed part of the Jung domain, before the Chinese had yet arrived and driven them out or assimilated them. The Li Jung were in touch on the east with the Chiang Jung, who dominated the Yellow River along its southern bank above Chên. All the hill country between the Valley of the Huang Ho and its tributaries, the Lo, the Yi, etc., as far as the Huai Mountains, was likewise peopled by the Jung—the Jung of the Lo, of the Yi, of Yang-chiu, of Man or Mao, etc. They surrounded the eastern capital of the kings of the Chou dynasty, the town of the Lo, or Lo-yi, situated near the modern Honan-fu, which they sacked in the seventh century, just as their brethren of the west had sacked the western capital, near Hsi-an, in the eighth.

Along the coastal region the mountains of Shantung were peopled by the Yi barbarians, certain tribes of whom persisted down to the end of the feudal period, in the midst of their congeners, who had been assimilated by degrees and not by brute force, and who had established real Chinese principalities, such as Chiu, Chi, Chou-lu, and others. More to the south, the border region between Shantung and Kiangsu Provinces was held by the Yi of Huai, who on the west adjoined the Hsiu. These latter must originally have occupied the whole country between the Yellow River and the Huai Mountains, along the middle course of the Huai and its tributaries. The last kings of the Yin dynasty, around the eleventh century B. C., had relations with them, and somewhat later their name was given to one of the nine Provinces into which the great conqueror kings of the Chou dynasty, Chao and Mu, about the ninth century B. C., divided their ephemeral empire. By the beginning of the historical period, however, beaten now on the north by the princes of Lu, now on the west by the dukes of Sung, their neighbors, they survived only in the eastern part of their former domain, around the present Hsü-chou, leaving behind them in the west only fragments of themselves. Of these, the most important, the Jung of Hsiu, held the country around the great bend of the Yellow River between Kʻai-fêng and Chʻao-chou and were finally subjugated only in 668 B. C.

Lastly, the whole basin of the Yangtse was peopled by barbarians grouped together under the general name of Man; brought rather late under Chinese influence, after the conquests of the ninth century B. C., and quickly regaining their independence, they kept it till

the end of the Chou dynasty and were civilized entirely through contact. One of the chieftains of the plain where the Han flows into the Yangtse conquered all his neighbors, founded the State of Chʻu, and took the title of king at the end of the eighth century. In Szechuan, the Chʻêng-tu Plain was occupied by the principality of Shu, while the tribes along the coast and the lower Yangtse, although at first under the rule of the kings of Chʻu, also finally set up as the independent States of Wu and Yüeh.

To sum up, ancient China, scarcely extending outside the basin of the Yellow River, comprised, toward the end of the eighth century before our era, two distinct groupings. Of these, one lay to the east, in the great plain of the lower Yellow River, while the other was in the west, in the Valleys of the Wei and the Fên. Between the two were interposed great masses of barbarians which separated them completely. This state of things was evidently very old and not at all due to the dislocation of an old Chinese *bloc* through the intrusion of barbarian invaders. The latter hypothesis is excluded by the very nature of the habitat of the barbarians. The latter were in fact masters of the uplands and of these alone, all the plain being in Chinese hands. But the paths of invasion in China are the plain on the east, and on the west the valleys of the Yellow River and its affluents; the mountains form obstacles, not passages. The theory advanced by De Groot [11] of Turkic invaders painfully conquering the barren and inaccessible mountains and leaving the lowlands to the vanquished is opposed to all probability.

A detailed examination of the geographical grouping of the Chinese and the barbarians in each of the two regions in the eighth century proves that the respective situations of the two groups were far from being identical. The Chinese of the Valleys of the Wei and the Fên were outsiders in the midst of indigenes whom they had not yet succeeded in assimilating or exterminating, and of whom important groups long survived in the midst of the Chinese. The distribution of their settlements shows how they ascended the rivers and installed themselves in the well-watered plains which they proceeded to cultivate, while leaving to the indigenes the uplands, difficult of access and of doubtful value for tillage. Even as late as the

[11] De Groot, Die Hunnen der vorchristlichen Zeit, p. 5, makes the Shansi barbarians Turks through a false etymology of their name, "Ti"; and he declares that they established themselves in the mountains, "favored by the circumstances that they found them nearly or quite uninhabited" (p. 28). The incursions of the Ti into Chinese territory during the seventh and sixth centuries suggested to him the theory of a "powerful empire" in the unknown north which had directed these, and with which the barbarians living in Shansi were in permanent contact (p. 28). Although our gratitude is due to De Groot for having undertaken a profound study of the chapters in the Shih Chi, of the first century B. C., and of the Chʻien Han Shu, of the first century A. D,. concerning the Huns, one can only regret that he has included in his work such hazardous hypotheses.

eighth century, when an anonymous scribe took various documents in prose and in verse and dovetailed them together to form the little treatise known as the Yü Kung or "Tribute of Yü," the Wei Valley seemed to him so undeveloped that he placed the rate of its impost as low as sixth in a scale of nine, although at the same time he rated the soil as of the first rank. Such an anomaly only the sparsity of the population or, which comes to the same thing, the slight extent of the cultivated lands, can explain.[12] Whatever theory regarding the origin of the Chinese civilization may be adopted, here they were colonists; this fact furthermore is so clear that all who have occupied themselves with the question, Legge, Richthofen, and others, admit it without dispute, only differing in respect to the country to which they assign the origin of these colonists.

With the people of the eastern plain the case was by no means the same. Their domain, in spite of its extent, was purely Chinese, no barbarian group occurring within it, either in the mountains or among the marshes. To reach barbarian territory, it was necessary to go beyond the frontiers, into the mountains of the west or east, or into the swamps of the south. No trace is to be found of any relatively late and still incomplete colonization, as in the case of the Wei Valley. In point of fact, had the Chinese of this region been intruders from elsewhere, in view of the entire absence of indigenous populations and the immensity of the territory in question, the assimilation or extermination of any such pre-Chinese population would have required a much longer time than it did in the west, where, however, the work was far less complete over a region of much smaller extent. Thus the settlements of the middle and lower Yellow River Valley must have been far more ancient than those of the Valley of the Wei.

There is nothing, however, to indicate that the Chinese civilization was of foreign origin and introduced into the Yellow River Basin by conquerors from without. On the contrary, it has every aspect of being a development on the spot of that barbarian culture once common to all the various peoples of the Chinese world, the Chinese themselves, the Tibetans, the Lolos, the Burmans, the T'ai, and the Miao-tzŭ, who, however, have advanced at such relatively different rates that they now find themselves in widely different stages of civilization. It is among the tribes of southeastern and not central or northern Asia, according to every indication, that the affinities of

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[12] Shoo King, tsl. by Legge (Chinese Classics, III, 125; tsl. by Couvreur, 69); cf. Conrady, China, 482. The tithe of the harvest, payable in kind, was the basal tax in ancient China, so that the relation of the soil to taxation was very close. In the Yü Kung each of the nine Provinces of the empire is assigned two ordinal numbers, depending in the one case on the quality of the soil and in the other upon the amount of the impost.

the earliest Chinese civilization are to be sought.[13] This common culture was characterized by the kinship existing among the languages, by a similar social organization, and by analogous types of religions. Chinese has no connection whatever with Turki, Mongol, Manchu, Korean, or Japanese; but on the other hand, it is closely related to an important family of dialects spoken by a group of southern peoples, the T'ai, who inhabit the Provinces of Yunnan, Kueichou, and Kuangsi, as well as the north of Burma and Tonkin, and whose southernmost branch founded the kingdom of Siam. It also shows less clear but still indisputable relations with the Tibeto-Burman languages—Tibetan, Lolo, Mosso, Burman, etc. In the Sino-T'ai languages, as far back as we can trace them, the words have always been monosyllabic and invariable, without inflection of any sort;[14] the system of tones formed an essential feature, each word being uttered in a tone whose elements of pitch and modulation owed their origin to the influence of the initial and final sounds. Aside from language, their essentially sedentary and agricultural civilization, their religion, closely intertwined with agriculture, and their aristocratic and feudal political organization, based upon the religious character of the system of land tenure, all connect the Chinese with their southern neighbors, while marking them off from those to the north.

Between the stock-raising northern nomads, ancestors of the Huns, the Mongols, and Manchus of the historical period, on the one hand, and on the other the savages of the Indo-Chinese peninsula, ancestors of the Moi of the Annamite Range, of the Cambodians, and of the Peguans, all incorrigibly anarchical, and upon whom foreign influence alone has at times been able to impose social groupings wider than the village, the tribes inhabiting almost the whole of what is now China, already constituted, long before their appearance in history, societies of an identical type, essentially sedentary and agricultural and strongly attached to the soil by religion and institutions. Thus by a curious turn of affairs the steadily advancing conquest and assimilation of the southern countries by Chinese civilization in later times seems to be only the reestablishment in modern form of a prehistoric state of affairs in which nearly all the peoples inhabiting the region that is now China once shared a common civilization.

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[13] The discovery recently by Doctors Andersson and Arne (Palæontologia Sinica, ser. D. Vol. I, fasc. 1. 2, Peking, 1923–1925) of prehistoric pottery whose ornamentation shows apparently indisputable relations with that of the west, does not prove, as Doctor Arne seems to think, the western origin of Chinese civilization, but only the existence of commercial relations across central Asia at a very ancient epoch. Cf. Pelliot, Jades Archaïques de Chine, p. 9.

[14] Bernhardt Karlgren, Le Proto-chinois langue flexionelle (Journal Asiatique, 1920, pp. 205–232), believes he has discovered traces of inflection in the use of personal pronouns in the "Chinese Classics"; but it seems to me difficult to accept his conclusions.

The Chinese accordingly seem to be the northernmost branch of these sedentary populations, the western branch being formed by the Tibeto-Burman tribes of Tibet, of Szechuan, and of Yunnan—the Tibetans, the Lolos, the Mossos, the Burmans, and others; the southern branch by the T'ai of southern China and northern Indo-China—the Shan of Yunnan and Burma, the Dioi of Kuangsi, the White and Black Tăi of Tonkin, the Laotians, and the Siamese; and the central branch by the Miao-tzŭ of Hunan and Kueichou. For these prehistoric Chinese, life was perhaps harder than for their more southern brethren. The great plain of northeastern China, comprising the modern Provinces of Chihli, Shantung, and Honan, where the rudiments of their civilization began to develop, was far from being the well-tilled land which it is in our own day. The Yellow River, which traversed it, had then a different course from its modern one. After a long detour past the foot of the mountains of Shansi it entered the sea by the present course of the Pei-ho, near Tientsin,[15] its innumerable branches wandering capriciously over the low-lying flat and almost dead-level plain, then called the country of the "Nine Rivers," because the Yellow River in this portion of its course was considered to split up into nine principal branches.[16] Every year, its course modified by the inundations, it sought out new channels. The low-lying areas, filled with water, formed great marshes which in course of time have become silted up, although remains of them exist even to-day. There were brakes of aquatic plants, of knotgrass, of rushes, of dolichos, and valerian, in the midst of which wild geese and cranes nested and fish swarmed. All about stretched patches of land, too wet for cultivation, covered with high grass interspersed with coppices of white elms, of plum trees, and of chestnuts. These, however, did not form a true forest. The latter only existed around the periphery of the plain, on the slopes of the mountains of Shantung on the east and of Shansi on the west, and with it began the domain of the barbarians. The dense undergrowth formed a refuge for the larger animals—tigers, panthers, leopards, wildcats, bears, wild bulls, even elephant and rhinoceros, and wolves, boars, and foxes, as well as smaller game of all sorts, herds of deer and antelope, monkeys, hares, rabbits,

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[15] M. Fujita, The River Huang in the Reign of Yü (Shinagaku, I, 1921, XII, 1–32), has tried to show that as late as the third century B. C. the region traversed by the Pei-ho from a point some distance above Pao-ting downward was still an arm of the Gulf of Chihli, into the upper end of which flowed the Yellow River; his argument, however, is scarcely conclusive, and I doubt whether, during the ancient period, the coast line was very far from Tientsin.

[16] The following description of the landscape and the fauna and flora of ancient China is based upon a combination of numerous brief accounts scattered through the Shih Ching, a collection of poems of the seventh and sixth centuries before our era. Cf. Biot, Recherches sur les moeurs des anciens Chinois d'après le Che King (Journal asiatique, IV, ii, p. 310 et seq.) ; on the particular question of the existence of the rhinoceros, see Laufer, Chinese Clay Figures, I, pp. 1–173.

and birds of every kind. These were hunted in great battues, held in winter, by setting the grass on fire. The regions forming the forest fringe were utilized either as pastures for domestic horses and cattle or as mulberry plantations for silkworm growing. The best lands, protected from floods by dikes, were regularly cultivated.

All these regions were covered with the type of soil called loess, the extent of whose distribution Richthofen has revealed, and which forms thick deposits, whence the Yellow River draws the muddy silt to which it owes its name. Spread widely over the foothills and over the Provinces of Kiangsu and Anhui farther south, it covers the terraced valleys of the Wei and its affluents in the northwest. Periodically fertilized by the summer monsoon rains, these loess lands have everywhere shown themselves favorable to agriculture. They appear to have been particularly sought after by the Chinese when, leaving the plain, they pushed up into the valleys of the west. The monsoons and the yellow loess soil seem to have been the real secret of the development *in situ* of the Chinese civilization. Geography here is in agreement with history.

Such was the land in which the prehistoric ancestors of the Chinese began slowly to emerge from the surrounding barbarism. There is no reason whatever to suppose that they had ever been nomads pasturing their flocks on the undergrowth of the lower Yellow River basin; on the contrary, everything goes to show that they were sedentary agriculturists.[17] But in the beginning instead of regular, permanent fields they can have had only temporary clearings analogous to the răi of the peoples of upper Tonkin, abandoned at the end of a few years in order to clear off another patch, leaving the undergrowth to spring up again.[18] The very curious custom of the ancient Chinese peasants of deserting their villages entirely from the middle of spring to the end of autumn and going to live in groups of three families each in communal huts erected in the midst of the fields[19] seems to me a vestige of a time when the temporary fields, or răi, were in the virgin

[17] The religious and political organization of the ancient Chinese, like that of their still surviving barbarian neighbors, was in essence a hierarchy based upon the possession of land. Besides suzerain and vassal lords, there were also, rank above rank, gods of the soil, not creative and fostering earth divinities presiding over vegetation, but guardians, suzerain or vassal, of definite territories; cf. Chavannes, Le Dieu du sol dans la Chine antique (Bibl. d'Etudes du Musée Guimet, Vol. XXI, pp. 437–525). The whole religious life was based upon the rhythm of agricultural life and especially upon the growing of cereals, millet in particular. If a pastoral stage for the ancestors of the Chinese must be postulated, it must be thrust back into an extremely high antiquity, for nothing of the sort survived at the dawn of history to suggest such a period, which if it ever existed must have long preceded the time when the ancient Chinese in common with the neighboring populations, T'ai, Lolo, Miao-tzŭ, etc., possessed an agricultural civilization.

[18] This is not a form of nomadism. Every group has its own fixed place of habitation, its winter village, moved only for weighty reasons; it was only the areas under cultivation which were changed from time to time. Moreover, every village had its territory precisely delimited, with boundaries beyond which its clearings did not extend.

[19] From the standpoint of religion, this practice was bracketed between two rites of similar nature, that of "carrying out the fire" from the house in the third month of spring and that of "carrying back the fire" into the house in the third month of autumn.

forest, far distant from the village. This would almost necessitate the practice of going to live near them each working season, returning to the village only after the harvest was gathered.

The hardest work of all was the reclamation of the land itself, of its conquest from river and swamp; this was a long and painful one, requiring the erection of dikes against the inundations and the digging of canals to drain and dry out the soil. All these tasks, however, had been accomplished so long ago that their very memory was lost in the mist of legend, and they were believed to have been accomplished by heroes descended from heaven at the beginning of the world—Huang-ti the Yellow Emperor, Shên-nung the Divine Plowman, and finally Yü the Great, the most celebrated of all.

> Yes, [all about] that southern hill
> Was made manageable by Yu.
> Its plains and marshes being opened up,
> It was made into fields by the distant descendant.

Or again:

> Thick grew the tribulus [on the ground],
> But they cleared away its thorny bushes.
> Why did they this of old?
> That we might plant our millet and sacrificial millet;
> That our millet might be abundant,
> And our sacrificial millet luxuriant.[20]

The lands thus brought under cultivation produced millet and sorghum in Chihli, rice south of the Yellow River, and wheat almost everywhere; there were grown also beans, gourds, hemp, and indigo. The fields, which were periodically reallotted, formed blocks of roughly 1 square li (15 to 20 hectares), each forming 1 ching, divided into 9 equal lots which 8 families cultivated in common, each family keeping for itself the produce of 1 lot, while that of the ninth, the kung t'ien or "public field," went to the king or feudal lord by way of tax. Close by, but scattered and almost lost in the midst of the plain, were erected little clusters of mud huts, the winter dwellings of the peasants, in groups of 25, forming the smallest religious and adminstrative divisions.

These little hamlets or li, of about 200 inhabitants (the 25 families of 3 ching) had each an altar to the god of the soil, a school, and a market.[21] In them the peasants shut themselves up every winter, each

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[20] Shih Ching, tsl. Legge, pp. 368–373.

[21] We only know this organization under the purely theoretical shape in which it is described by certain late rituals with Utopian tendencies; the figures are given in round numbers in order to obtain regular multiples. The cultivators of the 3 ching in reality formed 24 families, but the figure was rounded out to 25 in order to secure, in the first place, an even division of the li or hamlet into 5 groups of 5 families each, an important division because serving as base for military levies and corvées and providing at the same time an even figure of 100 families to every 4 li for the next higher division. These calculations were purely theoretical, and the real movements of population rendered them illusory.

family in its own house; but in spring they left them in order to go to live, in groups of 3 families together, in great communal huts in the midst of the ching; they then lived entirely in the open air, without returning to their abandoned villages until after the harvest. They thus produced for themselves all that they needed, grain, domestic animals, cloth, silk, etc., the surplus being taken to market. Every village, every hamlet, had at least one market situated on its northern side; in towns in which resided feudal lords, it was established by the wife of the lord at the time of the first settlement, just as the lord himself then erected the temple of the ancestors and the altar of the god of the soil. The market formed a large public square about which peasants and peddlers set up their booths, grouped in quarters according to the commodities sold, such as grain, silk, cattle, horses, slaves, pottery, and so on. The petty castles of the lords were situated far apart; in each lived the lord of the fief, for the whole of the great plain was divided into feudal domains, in the midst of his wives, his children, and his servants. About him was a little court of dependent nobles, most of them cadets of his own family or else petty vassals; these performed for him the functions of priests, scribes, and warriors. The castles were built after a uniform pattern drawn up in accordance with ritual principles. In the center was the audience hall, facing south, with a vast court in front where the functionaries and vassals ranged themselves according to rank at the great audiences. Flanking the audience hall on the west was the ancestral temple, and on the east the altar of the god of the soil; behind was another court with the residence itself, while in front a gateway led to the entrance court with its monumental south gate. The whole was surrounded by a wall and moat in order to guard against surprise attacks. All around were the houses of the ministers, functionaries, scribes, and priests, and also of the artisans and all those whose work was necessary at the court. Sometimes, but not always, an outer wall surrounded this agglomeration. But at best it would form only a small town; Mencius speaks of one whose outer wall was 7 li, or about 3,000 meters, in circumference, and it was held that "when the wall of a town, other than the capital alone, was over 3,000 feet, or about 600 meters, in length, it was a source of danger to the State."[22] The capital of the eastern Chou dynasty, Lo-yi, whose walls were 17,200 feet, or less than 4,000 meters, in circumference, was supposed as a matter of principle to be the largest city in the empire.

The more progress the Chinese made the more did they feel the difference between themselves and their less advanced neighbors, whom they began to look down upon as "barbarians." This distinction was accentuated by the invention of writing, at first appar-

[22] Mencius, tsl. Legge (Chinese Classics, Vol. II, p. 64). [I am unable to verify this reference; the passage does not occur on the page indicated. C. W. B.]

ently a sort of pictography, but which in time became a true script, in part ideographic, in part phonetic, the source of the modern characters. Of the first dynasty, the Hsia, founded at the southern base of Tʿai Shan, we know nothing. About the seventh century B. C. the dukes of Sung claimed as their ancestors the kings of the Yin dynasty, whose center of power lay about the great bend of the Yellow River where it debouches upon the plain. This dynasty also is half legendary; but the later rulers of its line, toward the eleventh century B. C., have left us the most ancient Chinese written documents known thus far, in the form of inscriptions engraved on tortoise shell.[23] It was from this region, probably toward the middle or end of the Yin dynasty, that colonists set out to carve for themselves domains at the expense of the barbarians.

There was no question of emigrations en masse of Chinese "tribes"; nor, on the other hand, does anything that we know of the ancient Chinese religion recall the "ver sacrum" of ancient Italy. These movements were undoubtedly headed by the nearly or quite landless younger sons of princely families, who set out thus to seek their fortunes at a distance at the head of little bands of clients, kinsmen, slaves, and people recruited by a sort of religious contract under an oath of mutual fidelity.[24] At this period, in fact, the Chinese world was split up into numerous petty feudal domains, of which, in the eighth century B. C. the plain of the lower Yellow River counted at least a hundred. These were governed by hereditary lords, the chʿu-hou, or "princes," as they were called, both political and religious rulers, subject only to the distant suzerainty of the king. Each of them, at his accession or during his reign, distributed lands to his brothers, his cousins, and his children as appanages for their support; it was undoubtedly those who were poorly endowed with land, or who were too distantly related to the lord to receive anything, or who, again, felt their lives threatened by the intrigues of a favorite, who expatriated themselves. The legend which connects the founder of the royal family of Wu, a barbarian kingdom of southern Kiangsu, with the ancestors of the kings of Chou and makes him an elder son

[23] The carapace of the tortoise was used in divination. Upon it was inscribed an inquiry addressed to the ancestors, and it was then exposed to the fire, responses being drawn from an examination of the cracks and lines produced by the heat.

[24] The traditions relating to the foundation of the principality of Chêng, near Hsin-chêng, in Honan, in 806 B. C., show its count, whom his duties as minister kept at court, far from his fief, on the one hand sending his son as governor in his place, and on the other making an agreement with certain merchants in regard to the clearing and improving of the domain; he enters into a religious convention with them, under an oath by which the two parties swear for themselves and for their descendants, the merchants not to revolt, and the count not to molest them in their trade; *cf.* the Tso Chuan, tsl. by Legge, p. 664.

The principality of Chêng was in China proper, so that it was a question here of the reclamation of lands within the Empire itself, and not of colonization abroad. The anecdote shows, however, how the recruiting of colonists and the organization of the hierarchy was carried on.

who retired of his own free will because his father wished to deprive him of the succession in favor of a younger son, has no historical basis, but it shows clearly enough in a somewhat too concise and idealized form the causes of these emigrations.

The t'ai-po or "Great Count" of Wu and his younger brother Chung-yung were both sons of the t'ai-wang or "Great King" of Chou and elder brothers of Prince Chi-li. Since the latter was wise and, moreover, had a holy son, Ch'ang, the "Great King" wished to give the power to him in order that it might pass on to Ch'ang. So the "Great Count" and his brother Chung-yung both fled to the barbarous Man of the land of Ching; they tattooed their bodies and cut their hair to show that they had relinquished the succession and had retired in favor of Chi-li. * * * When the "Great Count" sought refuge among the Man * * * the latter found him just; they became his followers and placed themselves under his protection to the number of over a thousand families.[25]

Flight among the barbarians became the traditional resource of the victims of harem intrigues; again in the middle of the seventh century, when the Prince Hsien of Chin sought the death of his son Ch'ung-erh in order to secure the succession to the son of his favorite Li-chi, Ch'ung-erh fled to the Ti with a few faithful followers and was well received by a barbarian chief, whose daughter he married.

Colonization was impossible toward the north, where the desert arrested the expansion of the Chinese; hence it could only proceed toward the south and the west. We do not know its history, for all the ancient history of China is unknown; it is possible, however, to form some idea of the stages through which it passed. Those who proceeded toward the south founded petty lordships in the Huai Mountains, among them those of Ch'ên, Shên, Ch'ai, Hsiu, and Huang. Then they reached the plain and began to create fine domains along the southern foot of the mountains, at Jo, Li, Sui, Erh, etc. They found there, however, a very different climate from that of the north and one which seems to have suited them ill and to have attracted few emigrants. Moreover, the barbarian chiefs of the region, at least those of the lowlands, allowed themselves to be won over quickly by Chinese culture; one of them, the lord of Ch'u, became a redoubtable rival when, in the last years of the eighth century, he subjugated the tribes of the Han-yang Basin. It was toward the west that the greatest push was made. It did not make a frontal attack upon the difficult mountains which rise abruptly from the plain along the eastern border of what is now Shansi, like the T'ai-hêng and Wu-t'ai Ranges and others, which remained the last refuge of the Ti barbarians. The colonists turned the obstacle by ascending the valleys of the Yellow River and its affluents, the Wei and the Fên. Most of them seem to have come from the region where to-day Shantung, Kiangsu, and Kiangsi adjoin, a region where

[25] Sseu-ma Ts'ien, Shih Chi, ch. 31, tsl. Chavannes, Les Mémoires historiques de Sseu-ma Ts'ien, Vol. IV.

the greater part of the princely houses belonged to the clans of Chi, Ssŭ, and Ying, members of which played the most important rôle in the colonization of the west. The Ssŭ had there their religious center, about the island of Yü-shan; there was situated the temple of their ancestor Kun, and to branches of the same family belonged the fiefs of Chêng, near Yi-chou, of Shên, near Ju-ning, of Ch'i, near K'ai-fêng, of Yang, near I-shui, etc. Those who had gone on into the west had settled along the banks of the Yellow River, around the temple which they had built to their ancestor Yü, son of Kun, at the mouth of the defile of Lung-mên. Thereabouts they founded a few small principalities; on the right bank of the Yellow River, Hsin, a daughter of which was believed to have been the mother of King Wu, founder of the Chou dynasty, while on the left bank lay Hsia, Ming, and Tung, the count of the last named being entrusted with the duty of representing his ancestor Kun, father of Yü, at a solemn sacrifice held by Prince P'ing of Chin in 535. Some had crossed beyond the Ch'in-ling Range into the upper valley of the Han; among them were the lords of Pao, from whom sprang the beautiful Ssŭ of Pao, the ill-omened queen who, according to legend, ruined King Yü of the Chou dynasty (771 B. C.). Mingled with these princely houses on the banks of the Yellow River, just as they had been in the eastern plain, for their fief of T'an was near Chêng, and that of Huang not far from Shên, etc., certain members of the family of Ying held lordships; Kêng on the lower Fên; Fei on the right bank of the Yellow River, at the mouth of the Lung-mên gorge; near by, Liang, opposite the mouth of the Fên; and farther west, Wang and P'êng-ya, on the River Lo. Outside this center had been founded still more distant domains; to the west, Ch'in on the upper Wei; to the east, Chao along the middle course of the Fên, at the extreme limit of Chinese colonization. The widest extent of lands seems to have belonged to members of the family of Chi; all the quadrilateral comprised between the Fên to the north and the Yellow River to the west and south belonged to lords of this house, Chiai, Hsia-yang, Yü, and Wei, while others had domains in the valley of the River Wei, at Juei near its mouth, at Shao, and at Kuo, near Fêngsiang. The most powerful of these lords was he of Chou, who held all the west of the plain, along the middle course of the Rivers Ching and Wei, as far as the edge of the mountains.

It is not impossible to form an approximate idea of the apparent date when certain of these fiefs were founded. The kings of the Chou dynasty, who ruled China from about the tenth century down to the third century before the Christian era, were descended from the family which had founded the principality of Chou on the

upper Wei. The tradition preserved in their ancestral temple carried the foundation of this domain back to the twelfth ancestor of the first king; this distant progenitor, Duke Liu, had been the first to clear the lands of Pin and had created there a great fief. Now the genealogical lists of the ancestral temples were carefully kept from very ancient times; the elaborate detail with which the cult of ancestors determined the number and kind of offerings annually presented to every deceased king or prince, according to his degree, necessitated great care. So in spite of the relatively late date of the writers who, toward the third and second centuries, collected these lists, they should not therefore be regarded as fictitious. An example of the confidence which may be accorded to the traditional lists, when the family from which they emanate is a long-established one, has recently been given by the inscriptions of the end of the Yin dynasty. The list of kings which these furnish differs scarcely at all from that which has been transmitted to us by the anonymous annalist who, during the last years of the fourth century B. C., composed the history of China known as "The Bamboo Books," and by the great historian of the late second and early first centuries, Ssŭ-ma Chʿien, in his Shih Chi. The fall of the Yin dynasty did not lead to the extermination of the vanquished royal family, whose descendants retained a portion of their hereditary domains under the title of dukes of Sung and only disappeared at the beginning of the third century B. C. A list of the dukes, preserved in the ancestral temple, has come down to us. Unfortunately there is no corresponding proof of the exactness of the genealogical list of the kings of Chou; but there is no reason to suppose it less correct than that of the dukes of Sung. The first certain date in Chinese history is the flight of King Li, the tenth sovereign of the Chou dynasty, who was driven from his capital in 842 B. C. So by counting backward the first 10 kings of the Chou dynasty and then the 12 dukes, their ancestors, as far back as Duke Liu, or 22 reigns in all, and allowing an average of 15 or 12 years to each, the establishment of Liu at Pin may be placed either at the beginning or the end of the twelfth century B. C. This is naturally only an approximation; but it is a probable one. It must not, however, be supposed that the colonization of the west only began then; there are no grounds for thinking that the lords of Chou were the first to install themselves there.

It would be interesting to know something of the life of the Chinese settlers in the west and south, how they established themselves, and what were their relations with their barbarous neighbors. No document, however, survives from that period. The best data we have are two religious odes in honor of the two ancestors of the

Chou family, to whom was attributed the founding of the family fief. These pieces of verse are not, of course, historical documents, giving exact accounts of the actions and actual deeds of these personages; but they go back probably to the eighth century B. C., to a time when the colonization, although forced to slacken owing to its very success, must still have been going on in certain regions. At all events, it is permissible to see in them an idealized description of the establishment of a Chinese adventurer and his clients in barbarian country and of the life which they led there.

There is no question of conquest in these pieces. Perhaps, in fact, it often happened that there was no conquest properly so called, but that the Chinese settlers secured peacefully from the barbarian chieftains a piece of land to clear, just as at the other end of the Old World the Greek colonists seem often to have obtained without difficulty ground upon which to establish a city and port. What is described is the most important rite connected with the act of taking possession, i. e., the founding of the town where, beside his own residence, the lord built the temple of his ancestors and the altar of his god of the soil. In one of these odes it is the Duke Liu who with his "numerous and crowded" followers abandons the first attempt at settlement after the first clearings and the first harvests.

> He tied up dried meat and grain,
> In bottomless bags and in sacks;—
> That he might hold [the people] together, and glorify [his tribe].
> Then with bows and arrows all ready,
> With shields and spears, and axes, large and small,
> He commenced his march.

He continues his search for a place favorable to settlement—

> He ascended to the hill-tops;
> He descended again to the plains,

until he finds such a one suited in all ways for permanent habitation. There he first constructs a ring wall of earth, and then offers a ritual repast to those who have accompanied him; he is then "acknowledged by them as ruler, and honored." In another ode it is the old duke, T'an-fu, who, driven out, so it is said, by the barbarians, leaves the spot where his people had—

> Made for them[selves] kiln-like huts and caves,[25a]
> Ere they had yet any houses.
> The ancient duke T'an-foo
> Came in the morning, galloping his horses,
> * * * and * * * looked out for a site on which to settle.
> The plain of Chow looked beautiful and rich,
> With its violets and sowthistles [sweet] as dumplings.

[25a] Regarding the loess cave-dwellings of Shensi at the present day, cf. Myron L. Fuller and Frederick G. Clapp, Loess and Rock Dwellings of Shensi, China (American Geographical Society, New York, April, 1924), pp. 215–227 and fig. 12.

The auguries having been favorable, he settles there and builds first the ancestral temple, and then constructs a small earthen ring wall of 5,000 feet, or about 1,200 meters, in circumference; next he erects his audience hall and his palace, and finally the altar to his god of the soil. As the work of clearing and reclamation goes on the barbarians continue to flee.

> The oaks and the vih were [gradually] thinned,
> And roads for travelling were opened.
> The hordes of the Keun disappeared,
> Startled and panting.[26]

In so far as the poets, under color of recounting events of the distant past, describe the sort of thing which was actually going on before their own eyes it would seem that the Chinese were often able to establish themselves peacefully in unoccupied tracts of jungle. These they then proceeded to clear and lay out as permanent irrigated fields, unlike those of the indigenes, who only made temporary clearings like the răi of the mountaineers of upper Tonkin, by burning off patches of forest. It was only in the sequel that the extension of colonization brought the settlers into conflict with the natives, whose agricultural practices demanded much space, and who accordingly, if unable to drive out the intruders, as they did, for example, according to tradition, the old duke, T'an-fu, had perforce either to abandon the country or else adopt the ways of the Chinese settlers and allow themselves to be gradually absorbed by them.

Thus from the great plain of the lower Yellow River, where it originated, Chinese civilization crept little by little into the farthest west, ascending the river valleys and outflanking the mountain ranges. The basins of the Wei and the Fên formed its highways of penetration. In Shansi the newcomers established themselves in the little plains traversed by the last-named river, working their way upstream as far as the great canyon above Huo, where the valley ceases to be passable. It was only later that they penetrated farther north, the basin of T'ai-yuan only becoming Chinese territory in the full historical period during the sixth and fifth centuries B. C. By that time, however, the Chinese expansion into barbarian countries had changed its character. Consisting no longer of isolated enterprises conducted by adventurers wishing to carve out domains for themselves at the expense of the barbarians, it had become a matter of systematic conquest on the part of Chin in the modern Shansi and Ch'in in Shensi, two of the great principalities which had just been formed by the consolidation of the greater part of the petty

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[26] Shih Ching, tsl. Couvreur, 287, 316; tsl. Legge, 437, 483.

fiefs of antiquity. These two States, and later, after the fall of Chin, those into which its territory was divided, were able to accomplish more easily than of old this conquest and gradual assimilation of the indigenes occupying the middle basin of the Yellow River, a task which constituted the greatest work of ancient China, just as the absorption, still far from complete, of the tribes of the Yangtse Basin and of the south has been the greatest work of the China of medieval and modern times.

ARCHEOLOGY IN CHINA [1]

By Liang Chi-Chao

On account of the visit of His Royal Highness, the distinguished Crown Prince of Sweden, who is the president of the International Association of Archeology, my colleagues have asked me to give, as an expression of our high esteem and welcome, a brief survey of the past and future of Chinese archeology.

I shall try therefore, though with diffidence, to say a few words on this subject. I am, however, aware that there may be mistakes and oversights, for which I ask your generous indulgence and to which I invite your criticism.

Archeology became a special branch of study in the Sung dynasty, which corresponds to the tenth and eleventh centuries. By that time printing had already been invented in China and had made great progress. Another special art, that of making rubbings of inscriptions, had already been invented before the Sung dynasty. These two arts greatly facilitated the study of antiquities by scholars, and the knowledge gained by them was thus given wider circulation, with the result that several of the well-known works written at that time have come down to the present.

We have a work entitled "Chi Ku Lu," by Ouyang Hsiu, a great statesman and famous literary figure. This book was written in 1061. It contains rubbings of inscriptions on bronzes and stones from his own collections and those seen by him, with commentaries.

Chao Ming-Ch'eng and his wife, Li Ch'ing-Chao, who was, by the way, the first woman to compose in that form of verse which we call Tsu, wrote in collaboration a work called "Chin Shih Lu." The nature and arrangement of this book are similar to that of Ouyang Hsiu, but the distinguished couple cast their net much wider.

Hseuh Sheng-Kung wrote a book entitled "Chung Ting I Chi K'uan Shih." This book differs from the two preceding ones in that it confines itself to inscriptions on bells and tripods. In those works inscriptions on bells and tripods are few, while inscriptions on stones

[1] An address delivered before the joint meeting held on Oct. 26, 1926, by the Geological Society of China, the Peking Society of Natural History, and the Peking Union Medical College, in honor of the visit of His Royal Highness, the Crown Prince of Sweden.

are numerous. With this book it is just the reverse. One distinguishing mark of this book is that illustrations of the original bells and tripods are reproduced.

Wang Hsiang-Chih is the author of a work called "Yu Ti Chi Sheng." This book on geography contains lists of tablets in each locality and describes in a very detailed way those places where stone inscriptions are found. This book therefore served as a Baedeker for the study of antiquities in different localities.

Nieh Tsung I wrote a book called "San Li Tu." This book contains pictures of ancient objects, ranging from vessels used in worship and household utensils and furniture to clothes and buildings. Although it can not be said that all the pictures are faithful reproductions of original objects, yet every picture is the result of careful study and investigation.

Li Chieh's book on architecture not only treats of the architecture of the Sung dynasty, but also contains a thorough study of the buildings of ancient times. For this reason it has great value in archeology. This book was formerly very difficult to obtain, but has recently been reprinted. I wish to present His Highness with a copy of this work.

Lu Ta-lin wrote a book called "Kao Ku T'u." The book contains illustrations of bells, tripods, and sacrificial cups which were done by skillful draughtsmen, reproducing the originals meticulously. In the case of objects where the inscriptions have disappeared through the wear and tear of time the shape is still reproduced. The names of the collectors are placed at the top of the explanatory notes accompanying the pictures or below the number of the picture. Archaic characters are explained and commented upon. Those words which are not decipherable are collected in the appendix.

Wang Fu's book, "Hsuan Ho Po Ku T'u," is a collection of pictures representing 527 bells, tripods, and sacrificial cups, grouped under 59 heads, and 45 seals grouped under 17 heads. Some of these illustrations are based on objects which the author has actually seen, others on objects of which he heard from other people. Notwithstanding the lack of investigation, the shape of all these objects seems to be correct. Although there may be mistakes in the phonetic values given to the characters, yet the form of the characters is preserved intact.

On the basis of this collection later generations can determine the types of sacrificial vessels used and also the language of that time.

Judging from the eight books just mentioned, we realize that archeology was greatly developed in the Sung dynasty. If the work had been carried on without interruption to the present time, what wonderful progress we might have made! Unfortunately, ever since

the middle of the later Sung dynasty, which corresponds to the twelfth and thirteenth centuries, down to the Yuan and Min dynasties, a change took place in the academic atmosphere in China; scholars began to devote their attention to metaphysics, so that while many people followed the prevailing fashion of dabbling in philosophy, few cared to enjoy the loneliness which is the fate of the scholar pursuing unpopular studies. As a result, archeology was neglected.

But in the beginning of the Ch'ing dynasty the enthusiasm for the study of archeology began to revive. In the middle of Ch'ien Lung's reign (circa 1765) some scholars began to direct their attention to this subject. A glance at the Bibliography of the Chinese Imperial Collection of Literature will tell us that we have 58 books relating to bronzes and stones.

During the 150 years from the middle of Ch'ien Lung's reign to the present marvelous progress has been made in the study of archeology. The whole field has been divided up and specialization has resulted in increasing accuracy. Famous scholars like Yuan Yuan, Weng Fang-kang, Wang Ch'ang, Sun Hsing-ye, Ch'ien Ta-hsin, Li Tsung-han, Wu Yung-kuang, Pao K'ang, Lu Yao-t'ung, Huang I, Chen Chieh-chih, Wu Shih-fang, Liu Hsin-yuan, Wu Ta-cheng, Wang I-yung, Tuan Fang, Wu Yuan, Pan-Tsu-yin, and living scholars like Lo Chen-yu, Wang Kuo-wei, and Ma Meng have enriched our knowledge of archeology. There are numerous other scholars whose names I shall not enumerate.

During the last 150 years the number of books on archeology is truly astonishing. I am familiar with at least 400 books which I consider as valuable contributions to this subject. The number of articles dealing with this subject, which are scattered through the different collections of essays, is legion. These writings are generally patterned after the works of Ouyang Hsiu, Chao Ming-ch'eng, and Hsueh Shang-kung, of the Sung dynasty, but the arrangement is much better, and a more careful classification has been made.

Some works, for instance, reproduce all the characters inscribed on the objects of antiquity. Others give faithful pictures of their original shape and form, and still others divide the material into different kinds and record for each object of each kind the year, the place, the time it was yielded from the soil where it was discovered, or whether a certain object is lost or is still in existence.

There are writings which deal with a special period. Notes on Metals and Stones of the Two Han Dynasties treats not only of the two dynasties in question but also the whole history of the subject up to the time when it was written. There are other works which treat of only one locality. "Notes on Metals and Stones of West and East Chekiang," for example.

Many writings dealing with antiquities in different localities are limited to small geographical divisions; some, for instance, are concerned with only one district.

There are other writings which are devoted to the recording of one kind of metal and stone inscriptions. Still others deal with books on this subject or tripods and bells or old coins and seals and marks. In short, every branch of archeology is studied in detail. So we see the progress in Chinese archeology during the last 150 years is very great, indeed. The achievements in the Sung dynasty pale into insignificance when they are compared with the work done in the last century.

Now, if we classify the objects that have been treated by the archeologists of the last 150 years, we get four kinds:

1. Stone.
2. Bronze.
3. Pottery.
4. Bones and tortoise shells, etc.

Stone.—In Chinese archeology inscriptions on stones occupy the most important place. The oldest stone inscription that is still in existence is the stone drum of the Chou dynasty (827–788 B. C.). There are 10 stone drums, one of which has been partly destroyed. They stand now inside the gate of Confucius's Temple.

Next in antiquity are the six tablets commemorating the glories of the Ch'in dynasty which existed from 246 to 210 B. C. They were placed in Shantung, Chihli, Chekiang, and other Provinces. Unfortunately they are now lost. Ten characters are, however, still left on the tablet which is in an old temple on the top of T'ai Shan.

Of stone inscriptions of the Han dynasty (100 B. C.) not more than 10 remain. We have more of the later Han dynasty (first and second centuries). Of inscribed stones from the Six Dynasties and the dynasties of Sui and Tang, which lasted from the third to the sixth century, we have a multitude.

The stone inscriptions of recent times are regarded by specialists as not very valuable and so are more or less neglected. Attention is chiefly directed to the periods preceding the Tang dynasty. These stone inscriptions are divided into the following groups:

Classics inscribed on stone.—Classics were inscribed on stones in the reign of Hsi P'ing of Han, Cheng Shih of Wei, K'ai Ch'eng of Tang, Chia Yu of Sung, Shu of the Five Dynasties, Kao Tsung of south Sung, Chien Lung of Ch'ing. The so-called "stone classics" of Han, Wei, and Shu have all been lost and only some fragments of them remain. As for the existing stone classics, the 12 classics of the Tang dynasty, of Kai Cheng (836–840) are still preserved in the prefectural college of Si-An-Fu of Shensi Province, and the 13 classics that were inscribed during Chien Lung's reign in the

Ch'ing dynasty (1750) are still kept in Kuo Tzu Chien. So much for Confucian classics.

As for Buddhistic sutras, many of them are inscribed on cliffs in the Provinces of Shantung and Honan. A large existing number of sutras are found in a mountain about 70 li northwest of Peking, called Ta Fang Shan, which has 7 caves where 5,000 Buddhistic sutras are inscribed on 2,300 large stones. The work began during the North Chih dynasty and was not brought to completion until the Liao dynasty. Altogether 700 years were spent on this gigantic piece of work.

Besides the stone classics, there are tablets recording the achievements of a certain period or commemorating certain great architectural undertakings or the achievements of certain individuals. Sometimes these tablets are placed inside a pavilion. Sometimes they are placed in the courtyard of large buildings or other places.

Grave tablets.—They are buried in a tomb and contain a record of the career of the deceased and his achievements.

Sculpture.—Sculpture flourished in the Six Dynasties and the dynasties of Sui and Tang (third to sixth centuries); Buddhism was then at its height, and so the practice of making Buddhistic images became very common. We have a number of these images handed down to us.

Stone carvings.—Stone carvings are found sometimes in large buildings, sometimes inside the graves, and sometimes beneath bridges. Generally they tell a story and in some cases have also conventional designs of different kinds which are symbolical.

The above are the five principal types. There are stone inscriptions of various other kinds, carvings on walls or bridges, which have come down to us. But of the five principal types of stone inscriptions, grave tablets with epitaphs and stone sculptures are the most numerous.

As grave tablets are buried in the graves, every year sees more and more of them come to light, although we have at present no statistics of the findings. And while it is possible that those that have been yielded from the soil may have been lost, the new findings more than compensate for the losses. Again, sculptures, carved as they are on the cliffs, are not easily damaged, and so many of them have come down to us more or less intact.

Of all these carvings or inscriptions there are rubbings, so that a scholar can, in the seclusion of his study, collect these inscriptions. The study of this subject is thus rendered easy.

The results of the researches of these scholars are as follows:

Every period or dynasty possesses stone inscriptions which throw a flood of light on the cultural changes of Chinese history. Besides,

as the Chinese always regard handwriting as an art, the famous handwritings are thus preserved and we can now see very clearly the different types of calligraphy that prevailed in different periods.

Mistakes or misprints in ancient books can be corrected by comparison with the citations or quotations contained in the stone classics and in the writings of different dynasties inscribed on the grave tablets and stone tablets.

The gaps in history can be filled and the mistakes in the historic works corrected. In this line scholars have done yeoman's work.

The carvings of ancient times we have no way of discovering. But we still can get some idea of the stone carvings of the Han dynasty. These stone carvings enable us to see the style of carving in the Han dynasty and also, by examining the things that are carved on the stones, the kind of clothes and furniture and household utensils used at that time. We can also see in the stories told on the tablets or stones the psychological basis of the mythology.

Again, from the images or sculptures we can see the changes in Chinese sculpture from one dynasty to another. We can also see that the changes in the sculpture reflect the changes in the religious faiths at different periods.

From some stone inscriptions we can find out the different religions that have found their way into China at different times. Even the religions that have died out can be traced back and identified.

The Nestorian tablet records the origin and the spread of one branch of Christianity into China and contains inscriptions in Syriac. This tablet is really unique in the world.

Again, in a synagogue erected by the Pluck Sinew sect, which, by the way, is the Chinese appelation for the Jews in Honan, there is a tablet bearing the date of Cheng Te of the Min dynasty, which proves the length of time the Jews have been in China.

There are inscriptions on stones which mark changes of boundaries, such as the Wan Tu tablet, Hsin Lu Chin Hsing Wang tablet, P'ing Po Chi tablet, Pei Chen tablet, Chiang Hsing-Pen tablet, Bilgid Khan tablet, Ts'uan Pao Tzu tablet, etc. From these inscriptions we can see the relations between China and her neighboring countries.

The Nestorian tablet which has just been mentioned contains facts about the spread of Christianity into China. But the monument of Karabalgasum also contains an account of the spread of Manichæism from China to Ouigur. A study of these monuments throws light on the diplomatic relations between China and other countries. From the monument of Orkhon and the monument of Tang and Turfan which contains inscriptions in two languages, namely, Chinese and the language of Ouigur, we can see the cultural relations between China and her neighbors.

Many dead languages we can understand by the help of these stone inscriptions. For instance, Chu Yung Kuan contains hexaglot inscriptions and Avalokita or Mo Kao Ku contains also hexaglot inscriptions, namely: (1) Chinese, (2) Tibetan, (3) Sanscrit, (4) Ouigur, (5) Bashpa Mongol, (6) Tangut. The date and the characters are similar in the inscriptions of both monuments. Thus the language of West Hsia and Bashpa can now be deciphered as they stand side by side with Sanscrit and Chinese.

Again, many stones with fantastic inscriptions recording contracts and agreements for the selling and buying of farm land have been discovered in the interior Provinces of China. We can know from these inscriptions what the civil law of ancient times was and how it actually worked.

From Chang Ching Hui Meng Pei, which contains inscriptions in both Chinese and Tibetan and which records the treaty in these two languages, we can see the laws governing the relationship between the countries that existed at that time. Also from the tablets which contain the transliteration of the names of official titles and names of persons, we know the pronunciation of the Tang dynasty.

The foregoing 10 points only indicate very briefly the work that has been undertaken by the archeologists interested in stone inscriptions, which is a great contribution to the understanding of Chinese history and culture.

In addition to stone inscriptions we have jade carvings which are similar to stone carvings and which form a special branch of study. The Chinese began to use jade in ancient times. The designs carved on the jades vary and so it is possible by examining them to determine their age. This also has a bearing on archeology.

Metals.—Metals include bronze and iron. Because of its durability, more bronze articles have come down to us than iron ones. We have bronzes dating from the three early dynasties, and all the following dynasties could boast of such possessions. But our ancestors did not pay much attention to them with the result that many bronzes yielded from the soil were lost. However, with greater interest in the antiquities, with improvement in connoisseurship and with better technique of rubbings, the loss of findings is diminishing. The objects of antiquity can be divided into the following kinds:

Inscriptions on bells and tripods.—In the Hsia and Yin dynasties the casting of bells and tripods was very common and so they became very numerous. The most important were the sacrificial vessels which were also used as a kind of dowry. In ancient times these things were highly regarded. Hence the saying, "However poor the gentleman may be, he will never sell his sacrificial vessels."

We recall that during the period of warring kingdoms they played a very important part in hostilities as well as in negotiations for peace. Such practices as "carrying away the heavy objects" were common. The vessels and bells of ancient times had been unearthed gradually, but also gradually lost. There are as many as 643 pieces mentioned in the books of Ouyang Hsiu, Chao Ming-cheng, and Hsueh Sheng Kung, but few remain.

However, a good many of them came to light later on; in the writings of the Ch'ing dynasty as many as 2,635 pieces are mentioned, all of which are scattered throughout the rural districts of China, not including those that are kept in the palaces, the number of which is probably even larger. Wu Ying Tien, Wen Hua Tien, and the old palace museum contain each a part of these treasures, the catalogue of which is not yet complete.

Most of the things in these palaces belonged to the pre-Confucian period and the language is very difficult to decipher. But thanks to the untiring efforts of the scholars, the language is now nearly completely worked out. As a means for the study of the linguistic changes in ancient times and the sources of the Chinese language, the material contained in the palaces is very important. Nine-tenths of the inscriptions on these treasures are comparatively simple and short.

Now that we can read the language before the period of Confucius we can correct many mistakes that occur in the history before his time and we can insert many historical events that are not recorded in histories in antiquity.

Then we can also see from these inscriptions the economic conditions of that time as well as the contracts and agreements which were a part of the civil law. That is why for the last 60 or 70 years the study of inscriptions on metals has been carried on with greater enthusiasm and ardor than the study of stone inscriptions and the study of metal inscriptions has been attended with greater success than the study of stone inscriptions.

Old coins.—The study of old coins was in the past done in an amateurish spirit, but it has now become a special branch of study. According to the statement of collectors, there are 7,000 varieties of old coins, and some of them are more than 5,000 years old. While I do not believe that the statement is reliable, I think it is quite true that some of them can be dated back 3,000 or 2,500 years. From these old coins, which were the medium of exchange in ancient times, we can infer the economic conditions of ancient China.

From the middle age of China down to the present every period has had its own coins. Whenever an Emperor came to the throne, new coins were minted, so that on examining the quality, size, and

the workmanship of these coins we can realize the economic conditions of the time. Again, the collectors of old coins are also interested in the different kinds of money that have come from abroad so that we have some idea as to the commercial relations between China and her neighboring countries.

Weights and measures.—The old weights and measures that still exist to-day comprise Chuan and Liang of Chin, Ch'ih of Han, and Hsin Mang, Ch'ih of Chin, Liang of Han, Chung Fang of Ho of Han. With the exception of Chuan, which is made of stone as well as of metal, the rest are all made of metals. We realize now that in the evolution of weights and measures the most important factor is the ruler, for from the Han ruler and the ruler that was used in the Chin dynasty we can find out the length and the size, etc., of the rule used in the Chou dynasty and we can get some basis for the study of the antique objects and the molds used in ancient times.

For instance, if in the study of old musical instruments we get the ruler used in Chin and also the musical notes for the flutes of Chin dynasty, we can, basing on the ruler and the musical notes, make a flute for the Chin dynasty which will be the same as that actually used by the people at that time.

Old seals.—Old seals are of two kinds, official and private seals. The collection of seals has become also a special branch of study. The largest collection exceeds 10,000. We can find out from these seals a number of official titles which are not mentioned in history, and also changes in geographical names. Besides, as carving of seals is still considered by the Chinese as an art, the discovery of the old seals has not only an antiquarian interest, but also gives an added impetus to the development of this craft to-day.

Mirrors.—Ancient China had no glass. The mirrors used at that time were all made of bronze. As late as the Tang dynasty and the dynasty of Sung, bronze mirrors were very common. After the Yuan and Ming dynasties bronze mirrors gradually disappeared.

At present the collectors of mirrors can show us different kinds of bronze mirrors, but the lack of statistics makes it difficult for me to give the exact numbers. If we examine the bronze mirrors, we find that the ornamentation consisting of animals, plants, or conventional designs carved on them is different one dynasty from another, reflecting the changes in the style of carving and also enabling us to see the circumstances under which China carried on intercourse with foreign countries.

These five are the principal types of bronze. There are miscellaneous articles, such as tallies used in war. The Ch'ing dynasty had tiger tally and the Tang and Sung dynasties had fish tally.

In former times the emporer in sending an expeditionary force to some place would give one half of the tally to the general in command of the army and keep the other half himself. The tallies are different in different periods and the study of these tallies is very interesting.

There were also spears and arrows of the Yin and Chou dynasties, some of which bear characters. If we take these arms of war and compare them according to the different periods to which they belong we can realize the conditions under which battles were fought.

Later on iron was used, but as iron is difficult to preserve many of the arms made of this metal were destroyed. However, some arrows and arrowheads made of brass are still preserved. Again, the bows with mechanical devices that belonged to the dynasties of Wei, Chin, and Han are entirely different in construction from those in former times and so serve as another kind of material for the study of conditions under which wars were waged at that time.

Ceramics.—Ceramics fall into two periods, the porcelain of the modern and the pottery of ancient times. Modern porcelain belongs rather to art than archeology, and so I shall not say anything about it. Ancient pottery can be divided into old pottery, tiles and bricks, molds, and tomb images. From the viewpoint of archeology the first two are very important, the latter two much less so.

Old pottery.—A great deal of the pottery that preceded porcelain has been taken out from the soil. In Shantung and Yechou of Chihli fragments of pottery have been unearthed and the number is by no means small. The characters inscribed on these fragments are all different from the ordinary characters on the tripods and bells. Some scholars find them to be the language used in the warring kingdoms.

We are still studying these fragments of pottery and when we succeed in working out completely the characters we shall find them to be great contributions to archeology. The measures and rulers of the Chin dynasty are sometimes also made of pottery, on which we can make out the characters.

Tiles and bricks.—The oldest tiles can be traced back to the Chin dynasty. The tiles used by the people of Chin during the period of the warring kingdoms can still be found. Tiles were very common in the Han dynasty; sometimes they bear inscriptions of the year in which they were made and so can be recognized at once. Bricks were even more common. All of the bricks used in the large buildings bear inscriptions and the year in which they were made. The collection of these old bricks has become a small branch of special knowledge.

Molds.—Some of the molds of drums and household utensils used in ancient times are still preserved. The most important ones are

the molds for the minting of money. Occasionally we stumble upon the molds of the Han dynasty, but the molds of later dynasties are very common. Many of the molds of the earliest movable type have been handed down to us. The oldest ones can be traced back to the Five Dynasties. The collection of molds, like the collection of tiles and bricks, has become a special branch of knowledge.

Grave utensils and images are those things which are buried with the dead. Many of the wooden images have been yielded from the soil. The shape of these wooden images and the clothes with which they were dressed are worthy of study. The wooden images that we have taken out from the soil belong mostly to the Six Dynasties and the Tang dynasty. The style of their clothes is very similar to that of the westerners. Their prominent nose and deep eyes are quite different from those of the Chinese.

From that we can find the traces of the intercourse between China and western countries at that time and also the influence on the sartorial fashion in China during that period. There are many other queer things which can serve as excellent material for the study of ancient customs.

Ox bones and tortoise shells.—From the time of Han, scholars as a whole were very ignorant of the culture of the three early dynasties. The so-called Wei Shu contain fantastic doctrines. But after the bones and tortoise shells have been yielded from the soil a part of the disputed historical events connected with the Yin dynasty begin to be cleared up. Chinese Turkestan was formerly regarded as having no cultural importance. But the discovery of wooden fragments makes us realize the importance of the relation between China and Turkestan at that time. Now let me give a brief account of the bones and tortoise shells.

The greatest impetus given to the study of archeology is the discovery between 1898 and 1899 of bones and tortoise shells in the Province of Honan. A good many of them have gone to Europe. In China, Lo Chen-yu and Liu Tieh-yun have collected not a few of these ancient relics. When they were first discovered people did not know for what purpose they were intended and found the characters inscribed on them very difficult to decipher.

Afterwards, through the careful study of a few great scholars, a large part of the characters was identified.

The result is that Chinese archeology is shaken to its foundations by this startling revelation. Many mistakes and conjectures of the etymology of certain words have now been rectified. Many great historical events which are recorded in old books and which have been unintelligible to us and regarded as fantastic and far-fetched have now been corrected.

What Confucius could not see we see to-day. What Confucius could not know, we know to-day. The mistakes Confucius made we are now in a position to rectify. Besides, we can infer from these findings the kind of society, customs, folklore, and psychology of ancient times.

We are still studying the language of the inscriptions on the bones and shells. We hope that scholars will gird up their loins for the task that is not yet completed. If we could succeed in deciphering all the characters we would achieve greater results than we have.

Wooden fragments.—Aurel Stein went to Chinese Turkestan on his archeological trip and discovered there many wooden fragments. These wooden fragments are in the words of a contemporary scholar "the ancient relics left in the desert." Most of these wooden fragments have gone to Europe, where they are being carefully studied.

If we look at the inscriptions on these wooden fragments we shall find that they have a great deal to do with the history of China. The things on these wooden fragments cover the period from the two Han dynasties down to the Six Dynasties, and so from an examination of them we can find out the conditions of Turkestan at that time and also the customs of that period.

Stone, metal, pottery, bones, and tortoise shells, these are the five principal kinds. I have only tried to touch upon the important aspects of the subject. Besides these, there are many others. As I am not a specialist, I shall not say anything on the other kinds. In short, the last 150 years have witnessed great progress in archeology, thanks to the untiring efforts of scholars. Although the technique that has been used is traditional, the contributions to scholarship are already very great. So much for the study of archeology in the past and at present.

I am of the opinion that Chinese archeology is still in its infancy and the future of archeology is very bright. From now on we should try to work in two directions:

Excavation.—In the first place, excavation is very important and necessary. So far the discovery of antiquities is more or less accidental and yet we have already in our possession a large body of valuable material. From now on we should go a step further and undertake excavation on a large scale.

Recently, in view of the fact that European and American scholars have come to China and achieved very good results through excavation, the Chinese scholars begin to feel the necessity of making excavations by themselves. If the Chinese scholars can really understand the methods of excavation and have really made up their minds to do so, the following suggestions may be worthy of attention.

Chinese Turkestan.—Recently European and American scholars have done a great deal of work in Chinese Turkestan; but I think there are still many places in that region which can be excavated,

because, as Turkestan is largely a desert which is constantly shifting, old cities could be easily buried underground by the sand and by the wind.

The chapter on Turkestan in the history of Han has a different story to tell from that told in the history of Tang.

The Turkestan described in the history of Tang is again different from the Turkestan of to-day. The causes of such wide differences can be easily conjectured. If excavation can be undertaken on a large scale, I am sure the antiquities rescued from the bowels of the earth will be ten or even a hundred times as many as we have to-day.

Upper region of the Yellow River.—In ancient times, in the upper region of the Yellow River, people often lived in caves. Even to-day there are many people living in this fashion. The soil in that region is very loose, so that caves and even cities might often be buried underground. So there must be many places where excavations can be profitably undertaken.

Lower region of the Yellow River.—Because of frequent inundations through the breaking of banks, many cities on both sides of the river have been buried. One proof is that in 1908, in the city called Chu Lu, an old city was discovered which was some 1,000 feet beneath the present city. In this old city stone inscriptions were found of the Sung dynasty (1111), so that we know that it was buried after 1111. The discovery of this old city was like the discovery of Pompeii. We found out the customs, fashions, household utensils, and handicrafts of that time. Many such cities in the lower region of the Yellow River must have been buried in that way, and so if we can make an excavation of these cities we shall certainly discover many important things.

Ancient tombs.—We know exactly where some of the oldest tombs are. But in China it is an immemorial tradition to regard the violation of tombs as highly immoral, and this tradition is very difficult to break. However, as this conception of the sacredness of tombs gradually dies out it will be possible to excavate the famous tombs one by one.

In 1916 in Kwangtung Province the tomb of Chao Hu, King of Nan Yueh, was discovered which contained different kinds of antiquities. Unfortunately they are all lost. The tombs that will best repay excavation are undoubtedly the tombs of Confucius and his descendants at Chu Fou. The Chinese people have great veneration for Confucius, and so not only the grave of Confucius but also those of his descendants have remained undisturbed.

If the tombs of his descendants were opened we could get a very clear notion of the conditions of China at different periods. Indeed, these tombs would make wonderful museums, containing as they do the history of several thousand years.

Other ancient cities and towns have suffered the ravages of war and have disappeared. If the ground on which they used to stand is dug into many antiquities can be found. Only it is not easy to undertake such work because of the opposition of the country people whose superstition is difficult to overcome, and also because the space to be excavated is too large. We have to wait until the country is politically more stable and the mass is educated to a certain point.

For the present, what we can hope to do is to train experts and improve our tools so that when the opportunity comes we can immediately set to work.

In the second place, we should try to improve our technique. Formerly the methods used were the methods of old Chinese archeologists, which were handed down from Ouyang and Chao with slight improvements from time to time. The old methods have good points, but they are by no means perfect. We hope that in the near future all the institutions for higher learning will provide for the special subject of archeology in their curricula and that we will adopt the methods of western scholars.

For instance, former archeologists made use of the designs on the objects to determine the age, which is certainly adequate. But when objects have neither designs nor characters the archeologists are at their wits' end. From now on archeologists should try to study the quality and color of the objects that have no external evidence and determine the date or age according to the criteria thus arrived at.

For instance, geologists can use their knowledge of the different layers of rocks to determine the period to which a particular object may belong. Anthropologists can use their knowledge to determine the differences in the structure of the body and head of a skeleton. These sciences can contribute, directly or indirectly, to archeology. In a word, we want to gather the material our predecessors have failed to gather. We want to apply the methods our predecessors have never tried to apply. We want to carve a new piece of land out of tangled woods and unweeded gardens.

With a large country like China, with such a long history and such an abundance of hidden treasures as China has, I am sure we are destined to play the most important part in the archeological world, if only we carry on our work with undiminished ardor and persistence. In this work many of our young scholars are now engaged.

At this opportune moment we are honored with the visit of His Royal Highness, the Crown Prince of Sweden. It is our sincere wish that His Royal Highness will graciously give us some valuable advice and help. And it is our unanimous sentiment that the visit of His Royal Highness will mark a new epoch in the history of Chinese archeology.

INDIAN VILLAGES OF SOUTHEAST ALASKA

By Herbert W. Krieger

United States National Museum

[With 16 plates]

Along the island-studded coast of southeast Alaska and of British Columbia are numerous villages of native Americans known as the northwest coast Indians. The native Indian and Eskimo population of Alaska to-day scarcely exceeds 27,000 in number, but of this number approximately 4,000 occupy the narrow fringe of islands and mountainous coast of southeast Alaska. This region extends from the lower Copper River on the north to the open waters of Dixon Entrance and the mouths of the Skeena and Nass Rivers on the south, a distance of more than 700 miles from north to south. The greatest width is but 140 miles, in latitude 56° N., and extends from the upper reaches of Portland Canal to the southern portion of Prince of Wales and Dall Islands.

Southeast Alaska is the traditional home of the Tlingit (Koluschan) and of the Haida (Skittagetan) Indians. Their villages and temporary settlements, fishing camps for the most part, are small, rarely exceeding a population of two or three hundred. Many of the so-called "winter villages" are now deserted, their former occupants having taken up new homes in the commercial towns or in the vicinity of the recently introduced fish canneries, where they establish new villages. Their former homes show evidence of neglect because their owners, imitating the white man's ways, are now living in new houses constructed of sawed boards, which are too often fashioned from makeshift or flimsy materials. The abandoned ancestral home, which, together with the painted war canoe and carved totem pole, represents the highest skill of the northwest coast Indian, is allowed to fall into decay.

Area occupied by the Tlingit.—All of southeast Alaska from Prince William Sound and the lower Copper River country on the north to the Queen Charlotte Islands and the valleys of the Nass and Skeena Rivers on the south was formerly occupied by the Tlingit.

The traditional neighboring people on the north were the Ugalakmiut Eskimo who lived east of the mouth of the Copper River. This tribe later became identified with the Tlingit. Athapascan tribes coming down the Copper River from the interior have tended to replace other Eskimo tribes formerly occupying the region surrounding Cook Inlet and Prince William Sound. These newcomers also engaged in trade with the northern Tlingit, gradually becoming modified in their speech and customs to resemble the Yakutat and Chilkat divisions of the Tlingit. The peculiar coastal culture of the northwest coast Indians, noted for its unique house architecture and wood carver's arts associated with a complex form of totemism, never advanced to any great extent beyond the inhospitable coast and glacier-strewn mainland north and west of Mount St. Elias. It does appear, however, in diluted form in the valley of the lower Kuskokwim River, on Nelson Island, and elsewhere along the coast abutting on Bering Sea.

Indians of British Columbia: the Tahltan; Tsimshian; Gitksan.—The native population of the mainland river valleys of British Columbia is separated for the most part from the island population of southeast Alaska by many fjordlike submerged canals, open water channels, and coastal mountain ranges, so that native intercourse with the tribes of the interior of British Columbia on the east was gained only over such water gaps as the Taku, Alsek, Stikine, Nass, and Skeena Rivers. The Indian tribes of the upper Taku and Stikine River valleys belong to the Tahltan group, a tribe belonging to the Athapascan stock; while the Tsimshian-speaking tribes occupy the valleys of the Skeena and Nass Rivers. Included with the Tsimshian are such tribes as the Gitksan of the upper Skeena and the Niska of the Nass River and Observatory Bay region. East and north of the Tsimshian are Athapascan tribes, who are primarily hunters rather than fisher folk.

The Haida Indians of Prince of Wales Island.—The Haida (Skittagetan) linguistic stock represents the highest development of the typical arts known as the northwest coast culture. This tribe occupies but a small area of extreme southeast Alaska, never having penetrated beyond the lower or southern third of Prince of Wales Island and the adjoining islands to the south and west. A line drawn from Klawak or Tlevak on the west coast of Prince of Wales Island to Tolstoi Bay, near Kasaan Bay on the east coast of the same island, represents the most northerly limit of settlements by the Haida. Native accounts and traditions refer to the migration of the Kaigani, a Haida family, from the Queen Charlotte Islands by way of Howkan and Klawak as recently as 150 years ago.

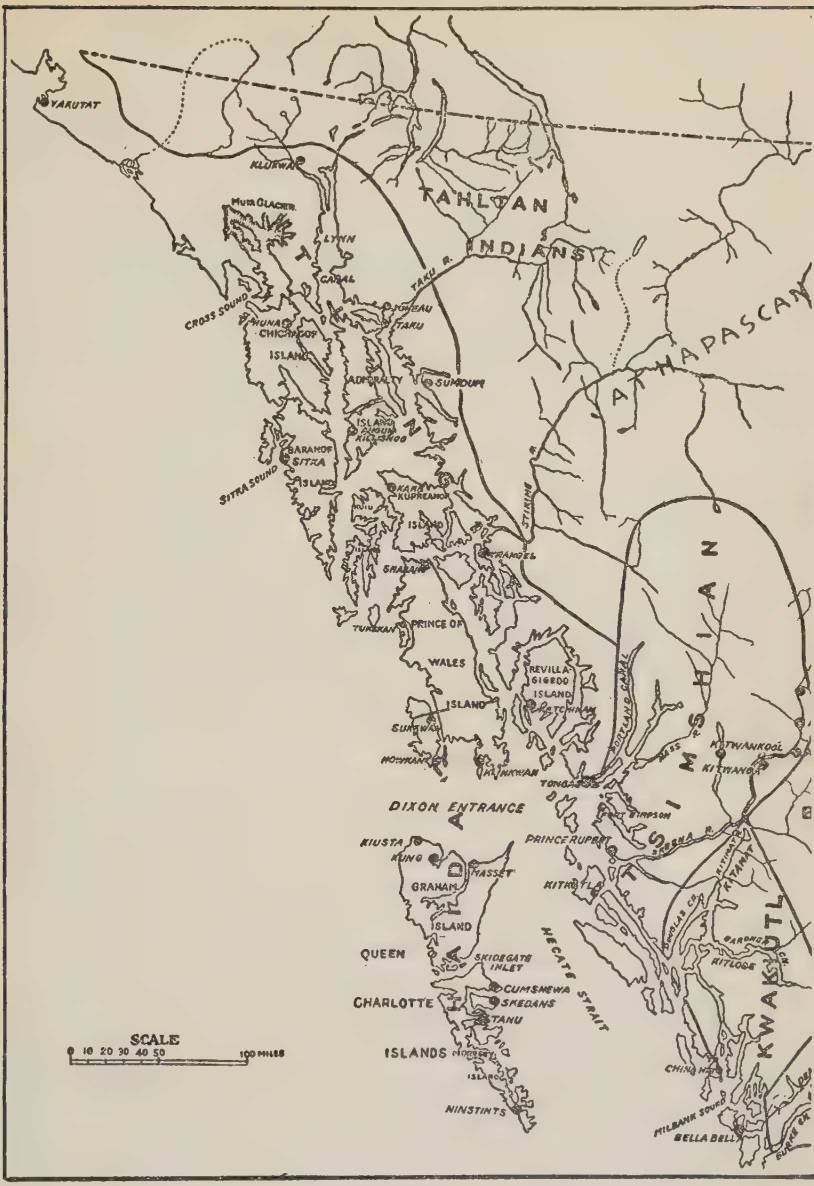


FIG. 1.—Ethnological map of southeast Alaska showing location of principal villages, many of which are now abandoned

The Kwakiutl and the Nootka of Vancouver Island.—The Kwakiutl and the Nootka, who possess a culture complex similar to that of the Tlingit and the Haida, live in British Columbia south of the Tsimshian. The area occupied by the Kwakiutl lies on the northern third of Vancouver Island and on the mainland of British Columbia.

An isolated group of the Kwakiutl lives farther north in the vicinity of Fitzhugh Sound. The Nootka occupy the western half of Vancouver Island and are closely related in speech and culture to the Makah, a tribe occupying the territory eastward from Cape Flattery and south of the straits of San Juan de Fuca in the State of Washington.

Physical characteristics and ethnic relationship.—Indian tribes occupying the southeastern Alaskan coast and the adjacent island archipelago appear to have been related at one time to the Aztec tribes of Mexico to whom they show startling physical and cultural resemblances. The skin has a pale brown color of a yellowish tinge; the hair is black and straight. There is but little facial pilosity. Occasionally males among both Tlingit and Makah stocks have a beard development much like that of the Japanese. Because of this and other physical resemblances northwest coast natives are often mistaken for Japanese. The nose is entirely different from the aquiline structure of the Sioux and other Plains Indians; it is more often concave or depressed. Eyes are brown and the stature is somewhat short and stocky. The head is very broad. The natives of southeast Alaska are shorter of stature and broader of head than are the tribes farther north. There is a marked contrast in this respect between them and the Eskimo of west Alaska, although the Aleuts and the Tinne Indian tribes of the Alaskan interior occupy a somewhat intermediate position.

Body deformation and objects of personal adornment.—Cranial deformation as practiced by the natives of Vancouver Island, the Nootka and Kwakiutl, and by the tribes of the lower Columbia Valley in the States of Washington and Oregon is unknown to the tribes of southeast Alaska, although distortion of the lower lip is effected by the women through the wearing of labrets placed in the lower lip.

Tattooing was formerly commonly practiced by both men and women, as was also the painting of the face on all ceremonial occasions. The piercing of the septum of the nose and of the lobe of the ear for the wearing of nose and ear ornaments was general. Other objects of personal adornment include necklaces of puffin beaks and of shells. Pendants of shell and combs of wood and of horn have designs etched on their carved surfaces. A variety of deep-sea shell, abalone (*Haliotis*), was used as an ornamental object of personal adornment, also as an inlay. The dentalium shell was prized and utilized in making pendants and necklaces.

Clothing.—Clothing was formerly made of skins or furs and of woven materials. The long fur robe worn by both men and women later gave way to the trade blanket. The Chilkat also wove a blanket from the wool of the mountain goat and cedar bark. These blankets incorporated totemic designs in pale green, black, and yellow colors.

The light green color was produced by permitting copper to corrode in urine, while the yellow came from a variety of tree moss; black dye was produced by boiling the bark of the hemlock.

A grass raincoat was worn with the shaggy, unfinished elements on the outside and with an opening cut out of the center for the head. A long fringed coat and leggings of tanned skins were worn by men and women, although neither sandals nor moccasins were common to the northwest coast. Woven basketry hats were worn by men and women. Such hats had a cylindrical projection on the crown and were known as cloud hats.

An apron of shredded bark was the characteristic woman's garment. Women as well as men had their bodies tattooed by introducing soot under the skin. Tattooing marks were applied principally to the arms and legs. Women carried labrets, or wooden disks, at the center of their lower lips.

Origin of the northwest coast Indian arts.—The origin of the arts of the northwest coast Indian has never been satisfactorily explained. It has been suggested that they may be ascribed to a recent Asiatic influence or to migration of peoples from the islands of the South Pacific, where the arts of wood carving are well developed. There is also something to be said in favor of a theory linking the Tlingit or Haida or some other northwest coast tribe with the Japanese. Both peoples are adept wood carvers, both are Mongoloid in race, particularly the males of one group resembling the males of the other. It is a common mistake for travelers in southeast Alaska to remark on the large number of Japanese standing or working about the docks.

Both people are fisher folk and good sailors living on opposite sides of the same body of water. Occasionally a boat has drifted across the northern Pacific, impelled by wind and current, and has deposited its occupants somewhere along the Alaskan coast. The strong North Pacific current which sweeps the eastern shores of Asia is deflected eastward so as to strike the American coast about Sitka, where a part is again deflected northward over the Aleutian Islands, while another part is turned south and sweeps the entire northweast coast as far south as Oregon.

When one turns to another area in the Pacific in search of relationships one immediately thinks of New Zealand where an equally large number of similarities of a different nature may be traced between the Haida and the Maori. Their system of tattooing and the painted designs with which they decorate their skin in order to identify the clan or family; the totemic, carved ornamental prow and stern pieces of their war canoes; their totemic system of house architecture, and their carved memorial columns; all make a striking case for culture diffusion.

These similarities seem unimportant, however, when note is taken of the far greater number of dissimilarities existing within the contrasted areas. Mention need here be made only of such deep-seated distinctions as that of race, language, and the principles underlying the application or execution of art designs within the two contrasted areas. Through convergence, and influenced by many factors of a similar kind, the totemic art of the two areas is apparently identical although an analysis shows fundamental distinctions in structure and in historical development.

Linguistic relationships.—The question immediately arises whether native America taken as a unit has more in common than has one coastal culture area in the American northwest with the culture of another island group of a different hemisphere separated by thousands of miles of water. The Pacific Ocean was unnavigable to any American tribe with canoes and other transportation facilities at its disposal at the time they first became known to early European explorers. On the other hand, the linking up of the coast Tlingit and Haida with the tribes of the American interior opens up entirely new view points to the student of the northwest. Totemic art such as flourished in southeast Alaska may possibly be connected with tendencies of a similar nature in middle America.

The art of totemic carving in wood, for example, and the production of images assuming human or animal characteristics, even the erection of small totem poles is practiced by the San Blas Indians of the Pacific coast of Panama. These Indians form a cultural link between the Peruvians and Maya.

Another line of inquiry is opened up by the researches of P. E. Goddard and E. Sapir along linguistic lines. They have determined that there exists an old relationship between the language of the Tlingit and that of the Athapascan tribes. This discovery was foreshadowed by early investigators but was never worked out in detail. The large Athapascan linguistic stock has representatives as far south as the Apache and the Navaho of New Mexico and Arizona, and certain Sonoran tribes of Mexico. It is the stock language of tribes occupying the greater portion of Canada west of Hudson Bay and south of the Arctic. The arts of these tribes must now be studied from the standpoint of any possible relationship with those of the northwest coast tribes.

The influence of early voyages by Europeans to southeast Alaska has led to a pseudodiffusion of native culture within historic times. As early as 1774 a Spanish ship sailed from the San Blas coast to southeast Alaska and explored the coast as far north as Sitka. Another later expedition from the San Blas coast traded with the natives of Prince of Wales Island in 1779. In later years travelers

and missionaries have greatly influenced the style of totemic wood carving as well as the design and totemic emblems themselves. J. G. Swan enumerates several instances of pseudodiffusion among the Makah Indians of Cape Flattery who selected their totems or heraldic crests from newspaper illustrations.

Climate and transportation of southeast Alaska.—Quite aside from any influence exerted by other tribes upon the natives of southeast Alaska, there remains the tremendous effect of environment upon their daily life. The extremely moist climate of the so-called Alaskan panhandle is well known. At Ketchikan, near the southern boundary of Alaska and the first port of call out of Seattle, the average number of days during the year with an appreciable amount of rainfall reaches a total of 235. The warm northwest Pacific current reaches the shores of southeast Alaska, moderating the climate far above that of the mainland east of the coastal mountain range. At sea level snow does not remain long before thawing. Fogs, mists, and heavy downpours of rain are frequent, while the constant trickle of running water, the odors of rotting vegetation, and the clouded sky are very annoying. The river valleys of the mainland of British Columbia have a hot summer coupled with an extremely cold winter. The Gitksan of the upper Skeena have, nevertheless, much the same culture complexes as those of the Haida and Tlingit of the milder and more humid coast.

The dense forests of the coastal archipelago and the mountainous interiors of the larger islands compel the natives to depend entirely upon their canoes for water transport and upon the sea for food during certain seasons. Forests of cedar, Douglas spruce, and hemlock supply materials for most of the native arts and crafts. The fondness of the coast Indians for working in wood becomes almost an obsession with them and finds expression, for example, in the long dugout canoes hollowed from a single cedar trunk. Cottonwood is used as a substitute in case no cedar suitable for the purpose is available.

Dugout canoes are constructed with a high ornamental prow and stern, shaped from separate slabs of cedar wood. Each has carved representations of mythical and realistic animal forms as totemic and ornamental embellishments. Some of these boats were formerly fitted with sails of cedar-bark matting and are from 40 to 60 feet in length. They have no rudder, but are steered with a stern paddle. Natives of Sitka, on Baranoff Island, are known to have sailed as far as Port Simpson on the Skeena, more than 300 miles distant. These huge war canoes carried as many as 50 men in the crew when on fishing or warring expeditions requiring such numbers. Not all dugouts used by the Tlingit and Haida are as large as the war canoe, but the small birch-bark canoe of the Tinne tribes of the interior is unknown

to them, as is also the skin-covered small boat, the kaiak, of the Eskimo.

Practically the entire coast of southeast Alaska from the Chilkoot River to the southern capes of Dall and Prince of Wales Islands is safe for the seaworthy canoes of the Tlingit and the Haida. A tempestuous body of water 40 to 60 miles wide known as Dixon Entrance separates the islands of southeast Alaska from the islands of the Queen Charlotte group. The notorious Cape Muzon, at the southern tip of Dall Island, and Cape Chacon, at the southern extremity of Prince of Wales Island, are fully exposed to any gale that may be blowing from the Pacific, yet they were regularly passed by the dugout canoes of the Haida on their journeys from Masset, on Graham Island of the Queen Charlotte group, and Howkan, Sukkwan, and Klinkwan, in the Kaigani territory on Prince of Wales Island.

It is significant to note that while journeys were readily undertaken at all seasons of the year, there are many coves and natural harbors with place names in Tlingit and in the Haida languages indicating places of refuge "where-one-waits-for-better-weather." The Indian of southeast Alaska is not the bold Polynesian sailor who embarks on a thousand-mile journey in his outrigger canoe equipped with his primitive chart of sticks and shells.

The large island of Revillagigedo lies east of Prince of Wales Island, with the smaller islands of Gravina, Annette, and Duke interposed. North of these are the islands of Wrangell, Kupreanoff, Chichagof, Admiralty, and numerous smaller islands. The channels separating these islands constitute what has become known as the Alaskan inland passage, now safe enough for large passenger ships, but formerly the scene of more than 500 wrecks since the acquisition of Alaska by the United States.

Native trade with the interior.—As most of the islands of southeast Alaska are covered with a dense forest growth, the number of inland trails frequented by the Indians are few. Bear trails and those of other animals are still utilized whenever possible. Such animal trails make unnecessary the task of clearing the dense undergrowth of ferns, berry bushes, alders, wild celery, skunk cabbage, devil club, young spruce, hemlock, cedar, and other plant life.

Rugged mountains embrace the interior of the larger islands and constitute inaccessible barriers to the native hunter except where they were crossed by trails or bisected by the many open water channels. Some of the trails were primitive trade routes. Trade was especially fostered by the northern Chilkat. When the Hudson Bay post was established at Fort Selkirk, there was a diversion of trade from the interior at the expense of the Chilkat Indians, so they

proceeded to burn down the fort. They were the original trade monopolists. On the mainland of British Columbia, trails existed along the great rivers and from one river valley to the other. The trails along the Skeena, Bella Coola, and Taku Rivers were extensively used.

Trade along such trails was limited for the most part to olachen oil which was exchanged by the coast tribes for skins, jade tools, copper, and white man's trade goods obtained from the tribes of the interior. Such trails were known as grease trails from the olachen or candlefish oil, which was a trade staple. Inland trails extended over the mountain passes to the headwaters of the Mackenzie and the Yukon Rivers. After the erection of the Hudson Bay post at Port Simpson near the mouth of the Skeena River and at other points along the Stikine, Nass, and Taku Rivers, regular semiannual trading voyages were undertaken by natives from such far-distant points as Sitka and Howkan.

The influence of the fur-trading companies on the life of the natives has been far-reaching. The Russian governmental fur-trade monopoly, the Russian-American Co., with headquarters at Sitka, rivaled the Hudson Bay Co. post at Port Simpson on the Skeena, and the other inland posts in diverting trade from the old native trails and portages. Sitka was maintained by the Russians as a trade center with the natives of southeast Alaska until the purchase of Alaska by the United States in 1867. The fort erected by the Russians was destroyed by the Tlingit in 1802, although Sitka remained the Russian seat of government. Port Simpson remained the other great center of native trade until eclipsed by the many cannery towns and the villages that developed as the number of whites increased.

Land ownership; settlements; villages.—The whole of the territory adjacent to the Indian villages was portioned out among the different native families or households as hunting, fishing, and berrying grounds. These lands were recognized as personal property and were handed down from generation to generation. Each family established a summer camp on its fishing preserve and hunted in the region back of it in winter. The privilege to hunt, fish, or to gather berries belonged only to natives having rights under native law.

Each stream had it owner, whose summer camp might be seen where hunting or fishing could be carried on most favorably. At times such streams were held in severalty by two or more families with equal privileges of fishing. At the close of the fishing season, the summer camp, with its smokehouse, oil pit, and fish-drying racks, was abandoned in favor of the family house located in the "winter town." Here the social life of the clans was fostered anew in ceremonial feasting and dancing throughout the winter months.

The number of permanent winter towns among the Tlingit and Haida Indians of southeast Alaska varied from time to time. In many sections of southeast Alaska several of these villages may be grouped together as a geographical unit. Such towns are located near enough to one another to permit visiting on the part of their inhabitants during the winter months. This grouping is not totemic but is merely geographical in the sense that a certain neighborliness is always fostered between near-by groups living in comparative isolation from the world. There were 20 or more population groups in southeast Alaska before their disruption by the establishing of new population centers based on the white man's industrial needs. Most of the native population is now in the incorporated towns, such as Ketchikan, and in the canneries.

Early exploration and trade.—The house architecture, sculpture in wood, horn, and slate, and the wood carver's arts of the tribes of southeast Alaska have aroused wonder and admiration from the time of their discovery by the Russian explorer Behring in 1741. Some of the earlier accounts of their peculiar arts date back to descriptions and observations of Captain Cook written in 1778. In 1775 Francisco Antonio Maurella, sea captain and scribe, participated in a Spanish expedition that reached the waters of Alaska as far north as Sitka. This expedition also traded with the natives of Prince of Wales Island. Other Spanish expeditions are recorded by Maurella as having traded with the Tlingit of Prince of Wales Island in 1779.

The French expedition under J. T. C. de la Perouse reached Cook's Inlet in 1786. A far more valuable narrative is that of the explorer Capt. Urey Lisianski, of the Imperial Russian Navy, who began a voyage around the world from Leningrad by way of the Atlantic and the North Pacific in 1803. He made keen observations upon native life as he saw it in the vicinity of Sitka and Lituya Bay.

The South Sea Co. was organized in England to carry on fur trade in the Northwest during the three years following 1785. George Dixon was a captain of one of the vessels of this expedition and wrote a journal in which the Haida and the Tlingit are described at length. The extensive surveys of George Vancouver on the northwest coast were undertaken for the English Government in 1791. His accounts of the life and culture of the Bella Bella, Tlingit, and Tsimshian tribes are extensive and valuable.

At an early date American and English trading ships visited the northwest coast to obtain furs. Skins of the sea otter were at first more highly esteemed than were furs from the interior, although the mainland is much more plentifully supplied with fur-bearing animals than are the islands. Fox farming in southeast Alaska has thus far been unprofitable due to the poor quality of fur from animals reared in the environment of the mild coast climate of southeast Alaska.

Food and animal resources.—The larger land mammals, such as the elk and moose, do not occur on the islands, nor do mountain sheep or mountain goat frequent the larger islands as in the past. These animals are hunted, however, on the adjacent coast range of British Columbia. Hunting expeditions are undertaken by the Tlingit and the Haida in order to obtain meat, furs, and antlers for making their dishes, ornaments, and implements. Bear and deer are generally distributed over the islands, and smaller mammals, such as the beaver, mink, and others, are also hunted and trapped.

A number of varieties of sea mammals as seals, sealions, and whales, including the killer whale, were formerly abundant. The sea otter and the fur seal were hunted many miles from shore in the open waters of Dixon Entrance by the Kaigani Haida of Prince of Wales Island. Varieties of migratory birds and wild fowl are prized but are difficult to trap. Wild geese are caught after they have shed their large wing feathers and are unable to fly. Wild fowl are also hunted at night with torches and are killed with clubs.

The salmon and its importance in the life of the natives.—Both Haida and Tlingit traveled far in season to obtain food. Journeys of hundreds of miles were undertaken in their huge war canoes, often for the mere love of adventure, but usually in search of new fishing grounds or to carry on trade with the tribes of the mainland.

The Indian had to follow the salmon to its new habitat whenever, for unknown reasons, it migrated to different spawning places far from those near the Indian's ancestral village. In his quest for food the Alaska Indian was often forced to abandon his well-established winter town with its large framed houses of split cedar slabs and decorative totem poles.

The salmon formerly entered every inlet and stream on their way to spawn in the fresh waters of the inland brooks and rivers. There are several varieties of salmon—the king, silver, sock-eye, humpback, and dog salmon. The humpback is cured in large numbers by the natives for winter use. The humpback and dog salmon are caught in shallow streams, while the king and silver salmon are caught with hook and line or with net. Formerly, salmon were never caught on a hook, although the silver salmon was caught with harpoons. Trolling has been introduced, where formerly the salmon were speared or caught in nets at the mouths of streams. Weirs were placed farther up the streams and the salmon were either speared or dipped out with scoop or dip nets. Since the advent of the canneries and the distribution of the best fishing grounds among the large fishing concerns, the Indian has had to discontinue the use of seines which he formerly worked on shares.

When caught, the salmon are turned over to the women, who clean them by cutting off the head, slitting the fish down the back, remov-

ing the backbone and the entrails, and cutting off the fins and the tail. The cleaned fish is then cut into long slices and hung on a wooden frame to dry. No salt is used. A slow fire aids in hastening the drying process and sometimes is continued in the dwelling houses. When cured the salmon are wrapped in bundles covered with bark, or are stored in chests for future use during the winter. The storage boxes must be guarded against dogs and placed out of reach of the children.

Halibut are treated in the same way as salmon, but are not so largely used for curing, as they may be caught throughout the greater part of the year. The heads of salmon and halibut are highly esteemed when they have become putrefied. The heads are buried in the ground and left there for days; then removed and eaten raw.

Importance of fish oil in native diet.—Herring and olachen, the so-called candlefish, are staple foods. They are caught with an implement resembling a scythe having several teeth placed at right angles to the shaft with the lower end of the shaft blade-shape so it may easily cut through the water. While a canoe is slowly paddled by one native, another manipulates this device. He thrusts it down in a school of herring, gives it a sweep, and impales as many as he can on the sharp teeth, then draws it up and dumps his catch into the canoe.

Herring are valued primarily for their oil, which is boiled out and boxed for winter use. The native method of extracting the oil from herring is to place the herring in large copper or iron pots. Formerly a large basket was used instead, into which hot stones were placed and the grease boiled out. The grease, after it is skimmed from the surface, is run into the hollow stalks of giant kelp, which have been tanned by soaking them in fresh water to extract the salt. They are then dried in the sun or in the smoke of a slow fire, and then toughened and made pliable with oil. In this form of container the grease becomes portable and an object of native commerce.

Oil is also extracted from the olachen. It was formerly considered the most desirable kind of oil. The native taste has shifted, however, and the present generation of Indians uses lard substitutes and bacon grease instead.

The olachen appear in the spring for a period of a few weeks only. The mouths of the great Skeena, Nass, and other rivers teem with them then and they are taken out with dip nets and dumped into a hole in the ground to putrefy. The oil is more easily extracted when the olachen are decomposed. When sufficiently decomposed the olachen are taken out of the hole and are put into a small canoe which is used as a caldron. Hot stones are thrown among the fish to sepa-

rate the fatty particles. When cooled the oil is put into boxes and stored for winter use. Fish oil is to the natives of southeast Alaska what butter is to milk-consuming peoples. Formerly a meal was not complete without the use of olachen oil, unless the less desirable herring oil was used instead. The Haida and the Tlingit preserved their dried fish and put up berries for winter use in it. Their bodies became so saturated with fish oil through daily use as to make the skin shiny, and there is no doubt that its use rendered the skin and body less susceptible to cold and moisture.

Salmon roe is also put up in oil for winter use. Like the olachen, it is permitted to putrefy in salt water on the beach before it is mixed with oil for the winter.

Herring spawn, for a brief period in the spring, is consumed in large quantities in its raw state. At the spawning beds every rock, seaweed, and the bottom itself is covered with their eggs. Natives throw branches of trees into the water and bring them out weighted down with spawned herring eggs. The spawn is exposed to the sun until cured, then soaked to loosen it from the hemlock twigs, and consumed immediately.

Fish roe as a food resource.—Fish roe is sometimes gathered from captured fish, and if not eaten at once is preserved. When pounded between stones and diluted with water it takes on a creamy appearance, and when mixed with snow becomes a native form of ice cream. When boiled with sorrel and dried berries it is molded into cakes an inch or more in thickness.

Meat and food preservation.—Fish and berries are the staple foods of the natives of southeast Alaska. The long and inhospitable winter requires that the natives lay up a stock of food for the winter. It is only comparatively recently, however, that they have found it necessary to salt or to dry meat for future use. It was formerly nearly always possible to obtain meat of many wild animals at all times. There is no taboo against eating the meat of the totemic animals, and it is doubtful if there ever was a taboo of this sort in southeast Alaska as there was, for example, in the totemic system of the Kwakiutl of British Columbia. The bear must always be spoken of in a respectful manner and the salmon may not be eaten during certain seasons, but cultural restraints and food taboos associated with ritualistic beliefs when they are found in southeast Alaska have in all cases their origin on the mainland of British Columbia. The Tsimshian were respected by the Tlingit because they acquired new ideas from them, while the Athapascan tribes were despised as their inferiors because of this very lack of social organization.

Fur-bearing animals such as the bear, beaver, land otter, and others are trapped, while deer are hunted during the rutting season with a call of birch bark which lures them to the hunter lying in ambush.

They are also caught when swimming in the water and are valued for their meat and furs. The meat of the porcupine and groundhog is also relished.

The flesh of birds or wild fowl is toasted on a stick before a slow fire without removing the feathers or the entrails. An interesting method of food preservation is not to remove the skin when game is killed until most of the meat has been consumed. Venison, however, is sun dried for winter use.

The hair seal and the fur seal were formerly hunted from the shore or in canoes. They were either shot with bow and arrow from ambush or harpooned as they lay on the sand or asleep on the water. The waters of southeast Alaska abound with food resources. Large numbers of invertebrates, as clams, crabs, cuttle fish, and oysters, are gathered at ebb tide. Marine algæ or seaweed and shellfish are consumed chiefly during the winter months.

Clams are boiled in quantities and are then impaled on a stick to be eaten later. Crabs and oysters are boiled or roasted. The small cuttle or devil fish is also a food resource, its tentacles being fried or boiled.

Berries constitute an important part of the native's food supply. No variety is cultivated, although a hardy variety of raspberry was introduced by the officers of the garrison formerly stationed at Fort Tongass when that place was the seat of a customhouse and the first port of call for American ships out of Seattle. This variety of raspberry is now cultivated in gardens at Ketchikan and is yielding large crops of berries. As a matter of record no plant other than a kind of wild tobacco (*Nicotineana attenuata*) was formerly cultivated by the natives. To-day there is a plentiful supply of potatoes, turnips, and other vegetables cultivated in small gardens throughout the entire region.

Berries grow wild in southeast Alaska in great abundance. There are currants, cranberries, salmonberries, strawberries, soapberries, huckleberries, and others. Huckleberries are preserved in oil. The soapberry is beaten into a cream resembling strawberry ice cream.

A variety of wild celery matures in May and is gathered by the natives. They peel off the outer skin and eat the inner stem as we do celery, but no salt is used. Salt appears not to have entered extensively in the list of native foods of Alaska before the days of the white man. Observations in the interior in the valley of the Yukon bear out this fact, as nowhere did the natives use salt either as a condiment or as a preservative.

The inner white bark of young spruce trees or of the hemlock formed a considerable part of the food supply of the Haida and

Tlingit. This was cooked. Scrapings of spruce bark were molded into cakes and consumed later, together with oil as a seasoning.

Native implements and industries.—It is interesting to observe the varying degrees of development reached by the comparatively isolated tribes of southeast Alaska in the different parts of the general culture pattern. If one were to rate the various culture areas of native America based on the sum total of their achievement, the tribes of southeast Alaska would rank next to Mexico and Peru. Yet the peoples of these two areas possessed domesticated animals and a complex system of agriculture while the northwest coast peoples had neither domesticated animals nor did they practice the cultivation of the soil. They were hunters and fishers only.

Copper was worked by them only to a small extent, as it was difficult to obtain. As soon as iron could be procured from the whites, metal was worked with considerable skill. Formerly tools were principally of nephrite, greenstone, or other hard stone. An excellent stone knife was collected by J. R. Swanton from an old Tlingit village site, illustrating the degree of excellence formerly attained in the manufacture of stone implements required to produce their many totemic and realistic carvings in wood, horn, and bone.

As fishing was the principal industry, the number of fishing appliances in use was quite large. Hooks of wood and bone, lines of spruce or cedar bark, kelp, or whalebone; gigs, gaffs, harpoons, spears, rakes, and various kinds of nets were used; weirs were built; bird calls and clubs were fashioned.

Bark was extensively utilized, the region being especially productive in raw material of this nature, and baskets of fine quality and mats were made in quantity. Boxes of mortised and painted wood were used as storage receptacles, and ceremonially also as mortuary pieces; spoons of horn and wood, and wooden and horn dishes were beautifully carved with totemic figures at the sides and ends. Such decorative objects are frequently inlaid with abalone shell and ivory. Some of the most artistic objects illustrating the totemic art of the Alaskan natives at its best are found on the carved and painted wooden boxes, and on the carved wooden bowls, spoons, and other utensils and dishes shaped from wood and antler horn.

Weapons and armor.—Bows and arrows are used in hunting. The bow is plain and consists of a broad stave; another variety, reinforced with sinew, is occasionally produced by the Tlingit. Clubs and daggers both plain and decorative occur in great numbers. Formerly the clubs were shaped from wood which was often intricately carved. Clubs of stone, antler, and whalebone and daggers of whalebone and copper were fashioned before contact was established with the traders of the Hudson Bay Co. and the Russians. Cuirasses of wooden slats

were made after the fashion of the suits of armor characteristic of northeast Asia.

A complication regarding the origin of the highly specialized art and material culture of the northwest coast Indians may be noted in their former practice of wearing armor consisting of slats and rods of wood or bone. This custom was clearly borrowed from the peoples of Asia, many of whom wear similar coats of mail. To offset the significance of such proved contact with Asia in comparatively recent times is the absence among them of certain other Asiatic traits, such as the making of coiled baskets, a trait which has spread throughout the tribes of western America as far south as Mexico and eastward to the Great Plains, including the tribes immediately surrounding the northwest coast area. These neighboring tribes have also borrowed another trait from Asia, namely, the construction of semisubmerged earth-covered houses. Such dwellings are typical of northern Asia over an area extending as far east as Europe, but are not characteristic of the northwest coast Indians.

Native American culture traits.—When one refers to the civilization of native America, one thinks immediately of those traits which reached their highest development in Mexico and Peru just before the days of the Spanish conquest—the practice of agriculture, together with irrigation, and the use of the hoe; the domestication of certain animals; the building of smoothed stone structures and temple pyramids. The growing of cotton, thread spinning, and the use of the loom; the making of pottery; the use of tobacco; and the wearing of sandals or moccasins, are the essential traits of native American civilization. Not one of these traits was known or practiced by the northwest coast Indian. But in his own specialties—in wood carving, in the artistic representation of realistic animal figures, in low-relief carving on wood, stone, and horn, in painting of realistic or mythical animal figures, and in textiles and in basket designs—the northwest coast Indian has no equal.

Phratries and consanguineal bands.—The social organization of the Tlingit and Haida is such as to divide the entire tribe irrespective of villages into two totemic classes or phratries, each exogamic and tracing descent through the mother. One phratry is known as the Eagle (or Wolf among the southern Tlingit); the other is the Raven. The Tsimshian have four phratries and the Gitksan have but three. Each phratry is made up of several consanguineous bands, popularly referred to as clans. Families belonging to these consanguineal bands may be scattered in several villages, so that the social organization of each village community is quite complex—more especially so as each clan has a chief living in each of the villages where the clan is represented. The organization of a consanguineal

band into a clan with an emblem or crest and a chief is readily understood, but the significance of the mutually exclusive phratries is more obscure.

At one time the phratry may have been a tribal unit; the presence of two phratries within the same geographical area may possibly be due to an early tribal amalgamation. That is, it is possible that the Eagle phratry coming from the mainland of British Columbia down the valley of the Skeena, as their traditions declare, found the Raven phratry in possession of the coast. In their quest for food and new fishing grounds, it happened that members of each of the two phratries would find themselves living within the same geographic unit or village. At Kasaan, for example, the Ravens occupied the houses on one side of the village, while members of the Eagle phratry occupied the other side.

Native villages of the Tlingit.—Taking up the several geographical units or villages of southeast Alaska as they existed before the development of the larger commercial towns and the numerous canneries and sawmills, one finds the native population grouped somewhat as indicated in the following tabulation. An interesting observation is the descriptive naming not only of places such as villages, but of the clans, families, chiefs, and even of the houses and totem poles.

The geographical groups belonging to the Tlingit are the Tongas and the Sanya or Cape Fox in the south; the Chilkat, Huna, Yakutat, and Taku in the north; and the Kake, Kuiu, Sumdum, Henya, Stikine, Auk, Hutsnuwu, and Hehl in villages occupying intermediate positions along the coast. Some of the villages belonging to the Tongas people are Tongas, "sloppy place," and Island Village, "sand-beach-around"; the Cape Fox people, Cape Fox Village, or "gasch"; the Chilkat people, the villages of Klukwan on Lynn Canal "famous town" (not to be confused with Klinkwan on Prince of Wales Island), Katkwaltu "town-on-the-point-of-a-hill," Chilkoot (located a few miles above Haines), Dyea, Skagway, and Decu (Haines).

The Huna people occupied a village at the mouth of Alsek River and another village, "silver salmon creek," north of Dry Bay. The Yakutat Indians lived at Yakutat, "where canoes stop" and at another village, "Laxayik." The villages of the Taku were the "town-at-the-mouth-of-Taku-inlet" and several others on the Taku River. The Kake people occupied a village on the northwest coast of Kupreanof Island while the village of the Kuiu people was located just across Frederick Sound on Kuiu Island. The Sumdum people lived on the mainland just south of the Taku River. The Henya people had the three villages of Klawak, Tuxikan, and Shakan, all located on the north and west coast of Prince of Wales Island.

The Stikine towns of Wrangell, "human-hip-lake," and old Wrangell, "alders-town," are located on Wrangell and Etolin Islands just south of the mouth of the Stikine River. One of the chief Auk villages is the present town of Juneau, while the Killisnoo villages of Angun, "right-behind-the-town," and of Kanassnu, "right-on-the-fort," are situated on Admiralty Island facing Chatham Strait. Some of the villages of the Sitka people on the west coast of Baranof Island have peculiar names as "fallen-stunned" (a man once fell there in a faint after eating quantities of halibut); "town-where-one-does-not-sleep-much"; "north-wind-blows-this-way," "town-straight-opposite-Mount Edgecomb," and Citka, "behind-Baranof-Island."

Villages of the Haida.—It is interesting to note the traditions associated with the early migrations of the several consanguineous bands or clans which number about 25 for the Tlingit. For the Haida, who are but recent arrivals on Prince of Wales Island, there is but one clan, the Kaigani. The villages of this group are located on the east and on the west coasts of the island. Sukkwan, "grassy-town," "place where they swim through," or, according to another informant, "wild-current-town," and Howkan, "island-with-sharp-points" (referring to stones in front of the village), are on the west coast of the island, while Klinkwan, "low-tide-town," and Kasaan, "town-on-the-point," or, "the-spot-that-looks-good" are on the east coast.

The southern third of Prince of Wales Island, occupied by the Haida in historic times, was originally also Tlingit territory as the many Tlingit place names adopted by the Haida would indicate. The two Tlingit clans, Ganaxadi and Teqoedi, according to tradition, were the first arrivals on this island and contested with the Kaigani Haida their possession of the southern portion. The Kiksädi, Ganaxadi, and Teqoedi belong to the Raven phratry and are the clans of Tongas and Cape Fox villages. Several conflicting traditions are related as to the migrations of the Ganaxadi who were the first to settle at Tongas, after having lived for a time at Tuxikan on the northwest coast of Prince of Wales Island where a Ganaxadi woman nursed a woodworm, now appearing as a Ganaxadi crest or totem. Another tradition associates the Ganaxadi with the people of Kuiu Island whither they had come from the south. They are later supposed to have removed themselves to the island of "tangak." It is this name that came to be applied to the village later known as Fort Tongass. The Tlingit name originally applied to this settlement was "cha-do-ku-ka" signifying a "sloppy-place."

Village Island and Tongas.—A group of Tlingit Indians, probably the Teqoedi, moved from Village Island, "da-sa-kok" (sand-beach-around), a small island less than a mile in length, located just south of Cat Island, to Tongas at the time the United States customhouse

and Army garrison were established there. Village Island was difficult to approach due the numerous strong tides and many sharp submerged rocks. There was no fresh water on the island and practically no vegetation. The discomfort of living on such an island devoid of all plant and animal life was compensated for by its inaccessibility of approach and freedom from attack by the Kaigani Haida, who practically surrounded them, or by the Sitkan and other northern Tlingit groups, who were accustomed to raid the Tongas, Sanya, and Stikine villages periodically when on their way to trade with the Skeena and Nass River tribes. No war canoe could approach Village Island without detection long before arrival.

After the acquisition of Alaska by the United States, Tangak, later Fort Tongass, became the first port of call for steamers sailing from the United States. The comparatively large white population of Fort Tongass was too great a lure for the natives of Village Island, who now migrated again so as to be near the protection of the United States troops. When Fort Tongass was later abandoned as a port of entry in favor of Ketchikan and the garrison was withdrawn, the village of Tangak (Tongas) also declined. Some of the natives removed to Ketchikan or to the canneries; others joined the colony at New Metlakatla, on Annette Island. This remarkable cooperative undertaking was established by Father Duncan in the 80's and flourished for a time only to again decline as newer communities were established where better opportunities for work were offered the natives.

The several family groups at Tongas, each with one or more houses, were (1) the Teqoedi or "bear people" having seven houses named, in the order of their location in the village from west to east, "bear-cub-house," "thunder-house," "stream-on-house," "bear-man-house," "mountain-basin-house," "town-end-house," and one unnamed cabin. The owner of the "town-end-house" has the rather characteristic name of "angry-mouth," while the owner of the "bear-man-house" is "hibernating."

The Wolf people have two houses near the east end of the village named the "forested-island house" and the "town-center-house." The Raven people (Ganaxadi) have five houses scattered along the village front named, in the order of their location from west to east, the "island-sand-bar-on-house," the owner of which bears the distinguished name of "treating-each-other-like-dogs," an impertinent reference to the peculiar habit that ravens have of dragging about the dead body of another raven; next in the somewhat irregular line of houses facing the beach is the "starfish," house of the Ganaxadi clan chieftain known as "home-of-big-doings"; this is located near the "raven-house," followed in turn by the "shoreward-

floating-house," and the "fort-house." The clan whose emblem is the killer-whale live in the "flicker-house," while the "Sea-lion people" have the "sea-lion house," the chieftain and owner of which is known as the "dancer,"

The village of Kasaan.—If we now take, by way of illustration, the village of Kas-a-an, a winter town of the Haida which fronts on Skaul arm of Kasaan Bay, on the east coast of Prince of Wales Island, similar conditions are found. Kasaan, like most of the native villages of southeast Alaska, is abandoned. Its former occupants have moved to fish-cannery settlements or to the larger towns like Ketchikan where a number of occupations and industries await them. Indians of Alaska have adopted the white man's ways, and have never been wards of the Nation like the Indians assembled on reservations within the United States. They are considered citizens of the United States and have all the privileges of white citizens under the Territorial Government of Alaska. The United States Bureau of Education, under the Department of the Interior, maintains schools, hospitals, and orphanages throughout the territory for the benefit of the native population which otherwise is left entirely to its own resources so far as the Federal or Territorial Government is concerned.

The village of Kasaan with the surrounding forested area including about 40 acres has been set aside as the national monument of Old Kasaan by Executive order in 1907. This order was amplified by the presidential proclamation of October 25, 1916. The abandoned village to-day consists of the ruins of houses and memorial columns. Many of the columns or totem poles, profusely decorated with carvings of animal and human figures representing the family crests are still standing. The village itself is overgrown with alders and dense masses of the salmon berry. The small black bear comes to the village site and adjoining grasslands early in the spring to feed on the succulent grasses and tender undergrowth. Later, in the fall of the year, it comes down to the shallow streams near by to fish, and deer come down from the hills to feed in the clearing. As the island is uninhabited for many miles in the vicinity of Kasaan, other varieties of game are also abundant.

The view from the village site is beautiful, including as it does the distant islands with their hills and occasional snow-capped mountains, and the intervening water channels and inlets. It is said that when the Kaigani Haida first migrated up the east coast of Prince of Wales Island, the spot was chosen as the site for their winter village as it was the "only place that looked good." The name Kasaan is said to signify, therefore, "pretty-place," although in Tlingit speech the term may be translated as "town-on-the-rock"

or "town-on-the-point." J. R. Swanton thinks that there is uncertainty as to whether Kasaan and the village of Howkan on the west coast of the island were occupied as towns by the Tlingit before they were settled by the Kaigani. It is certain, however, that the invaders destroyed the Tlingit village of Sukkwan on the west coast. It is also certain that it was about this time that there occurred the general exodus of the Tlingit clan of Teqoedi from Prince of Wales Island to Cape Fox and Tongas.

The narrative of the coming of the Kaigani Haida to Kasaan is an involved one and includes a story of family dissension culminating in the murder of one chief by his own brother, who was also his rival. The murder caused the villagers to take sides and led to the removal of the slayer and his adherents from their ancestral homes in the Queen Charlotte Islands far to the south and to the ultimate settlement of Kasaan. One branch of the Kaigani moved up the west coast of Prince of Wales Island, while another smaller group journeyed up the east coast.

House architecture.—Family life among the Haida was communal and consequently led to the construction of large houses, large enough to shelter two or three generations and two or more social classes. The chieftain of a clan and his immediate family were always surrounded with a group of lesser rank and with slaves. The house floor was arranged in concentric platforms, each succeeding platform being built on a level 2 or 3 feet above the one beneath, beginning at the centrally located deeply excavated fireplace and pit, until the outer platform or the one next to the walls of the house was reached. This platform was flush with the ground level on the outside. Long and thick retaining slabs of hewn cedar formed the retaining walls of each platform, and at the same time a support or back rest for those occupying the platform tier just beneath.

A section of the house was assigned to different divisions of the large family. The head of the family, who was often the chief of the clan as well, together with his wife, occupied the place of honor on the platform back of the carved house posts at the rear of the house. The slaves gathered and slept at the front or least desirable part of the house nearest the only exit.

The fire burned at the center of the house, on the lowest of the excavated sections of the floor. In one house at Tongas nine distinct floor levels are excavated; ordinarily there are but three. The fireplace is a squared section of bared earth or stone surrounded with a hewn log or with stones. Members of the family slept on the fireplace floor level during the cold or inclement weather. They lay either on the bare floor or on mats of woven cedar bark, with their feet toward the fire.

The houses at Kasaan were placed in an irregular row facing the shelving beach. The memorial or totem poles at the front of the houses are in some instances at the water's edge at high tide, and the action of the salt water on the base of such poles is such as to preserve them from decay. Those farther removed from the beach are much rotted at the base.

The framework of the house and roof rests upon four posts commonly hollowed at their back. Upon the main house posts rest two large unhewn log plates extending the full length of the house without any other support than that of the end posts. All material of which the house is constructed, such as the posts, plates, purlines, cedars for making the slab siding and end walls, and split slab "shakes" for the roof was towed to the village site. Skids were used to haul the material near the proposed location of the house. Suitable cedar and spruce in southeast Alaska grows only in certain favored places where soil deposits are thick enough above the rock substratum to support their growth. The work of smooth finishing and assembling is undertaken at the site of the house to be erected.

Erection of a house or totem pole was the occasion for much jollification by the Indian, calling to mind those social gatherings which formerly attended barn raisings in the United States. The day the house was to be erected was made known to the natives of neighboring villages in advance. Rivalry sometimes developed between competing clans, each of which was assigned a different log plate to place into position. The top purlines, together with the huge log plates, form the supports for the roof, which is covered with split slabs of wood and bark, secured by superimposed crosspieces and stones. In some of the newer houses at Kasaan large spikes of copper firmly secure the spliced beams and girders that extend from one longitudinal plate to the other. Usually there are only wooden pins pegged in at strategic points. The method relied on most for holding the framework together was dovetailing and interlocking mortises at the place of juncture of all beams and girder plates. Mere weight sufficed to keep the two main log plates in position.

Every native house in southeast Alaska formerly had a smoke hole at the exact center of the gabled roof. This was left open at all times except during cold and inclement weather. It was surmounted by a shutter, which was closed in the direction of the wind, but could be opened when the wind blew from the other side. An axle beam in line with the peak of the roof permitted this shifting of the shutter. When the wind changed and blew down the smoke hole a rope was pulled and the shutter revolved to a position against the wind. As the rectangular native house of southeast Alaska always faced the beach, and as the wind blows practically always up or down channel, such a shutter, movable only in two directions, was satisfactory. The

smoke hole was the sole opening to the house, with the exception of a small door, which in many houses was through the base of the totem pole. There were no windows.

According to old accounts, the erection of a large communal house was attended with intense rivalry. The entire procedure, together with the festivities that followed the completion of the task, was the cause of much bad blood between neighboring villages.

Totemism in southeast Alaska.—A totem, according to the definition of J. G. Frazer, is a group or species of material objects which primitive man regards with superstitious feeling and respect in the belief that there exists between him and every example of that species a close and peculiar relationship. This definition is generalized and may be applied to many varying forms of totemism observed throughout the world. The term "totem" was taken from the language of the Algonquin Indians, where a form of totemism was first observed. It is obviously impossible to connect totemic manifestations occurring in many parts of the world among primitive tribes of all races. It is rather the naturalistic view of primitive man, according to which he regards himself as a part of the living world in which he finds himself, that leads to totemic expression.

The totemic expressions of the northwest coast tribes are probably traceable to the gradual acquisition of numerous personal charms and fetishes belonging to representatives of a clan as a unit. Such personal fetishes as are accepted by the clan become conventionalized; they are also tempered and directed by the peculiar physical and cultural environment.

A certain amount of borrowing from neighboring Salish and Athapascan tribes of the interior by the coast tribes or by the interior tribes from the Tlingit or Haida is indicated by the ancient wide distribution of certain stone and other cultural objects, as the carved stone bowls with carved figurine heads at the sides; the peculiar stone ax, adze, jade tools; and the realistically carved human and animal figures in stone, wood, horn, and bone. Realistic sculpture of human and animal figures was formerly practiced by tribes from the California coast northward. It is interesting to note in this connection that carved human figurines in wood and carved images of fish and of land mammals are commonly found beside the dead houses of some of the interior tribes of British Columbia and of some of the Eskimo tribes of Alaska. Not merely the carved images but the dead house itself is identical with those formerly built by the Tlingit.

Memorial columns and totem poles.—The erection of a memorial to one's maternal uncle of necessity includes carved representations of animals and events illustrating the traditions and genealogy of the family, together with carved images of the family animal totem or crests which are the reputed animal progenitors of the particular

clan and family to which the owner belongs. All this does not preclude, however, the right of the owner to introduce carvings illustrating some particular experience or event in his own life which might add weight to his bid for fame.

Many people think of artistic design as something tacked on, something supplementary to the essential part of an object. That useful things may in themselves be pleasing in outline without conscious additions made for artistic effect is not always realized. The art of the northwest coast Indian is unusual in that the totem pole which he erects is pleasing in itself, although not intended primarily to please but rather designed to impress the beholder with the owner's greatness, wealth, or position in society, and to induce respect for himself as the heir of the family crest and totem, all of which are expressed on the pole, usually at the base, center, and top. The Indian has inherited the right to the crests and totems representing the traditional animal protector of his uncle or mother's brother, together with his mother's family or clan name and rank.

Much stress is laid on the possession of wealth. The desire for the accumulation of property stirs the Indians to the limit of their effort and ability. Religious ideas and mythical wealth-producing, half-animal creatures are called to aid in the pursuit of gain, so that many figures carved on the totem pole represent mythical beings whose presence there insures the prosperity and future wealth of the owner.

The most important thing in the life of the Indian is his crest or totem. Representations of this animal crest are placed on every conceivable object of daily use; they are even tattooed on his arms and body and are painted on his face. The inheritance of the proper kind of a crest or totem determines an individual's chances for success and for a favorable standing in the community. As he inherits the crest or totemic animal protector from his mother's male relatives, he makes it his business to erect a memorial column or tombstone to his maternal uncle as soon as he is financially able to do so. This totem has carved on it the symbolical and often distorted or simplified animal figures representing his inherited family glory or experience. It may be only after years of saving and effort that an Indian is able to erect the column which firmly establishes his place in the estimation of his fellows.

At the time of the erection of his totem pole to the memory of his maternal uncle, it is customary to give away a large amount of property such as blankets, canoes, and in former times even slaves. Such feast or property distribution has come to be known as a potlatch.

The giving of a potlatch by an Indian establishes his right in the community to a totem pole. The amount of property distributed among the clansmen who erected the pole depends upon its size, and the height of the pole, in turn, is determined by the number of animal crests or totems and the rank of the maternal uncle which the builder of the totem pole is to inherit. An Indian would be laughed at by his fellow clansmen if he erected a large pole but did not possess adequate means to distribute sufficiently substantial gifts at the time of the raising of the pole or if he assumed animal crests which were not traditionally his to assume.

Family emblems or totemic crests.—Any unusual experience in the life of the individual may be incorporated in the carvings on the totem pole. One pole at Tongas has the carved figure of a ship under full sail. This pole belonged to a woman who was the first of her village to see such a vessel.

A carved figure on another pole also at Tongas represents the experience of an Indian who once acted as host to a former Secretary of the Interior who was visiting Alaska. The Secretary was asked to sit on a pile of fine furs in the house of the Indian. At the close of the interview he was told that he was forgetting his furs. "It is the custom of our people," said the Indian, "that what a visitor sits upon is his." When the Indian's totem pole was erected later by his nephew, the former Secretary of the Interior was represented on it dressed in a frock coat, stovepipe hat, and checked trousers.

The story is told of another pole, also located at Tongas. This pole belonged to an Indian of the Bear clan (Teqoedi); that is, the family protective or totemic animal crest was the bear. This Indian had at a former time given a potlatch or feast to a rival chief whose crest was the killer whale. The rival chief lived at Wrangell and later, through drunkenness, lost all his property so that he could not give a potlatch in return, which was the customary thing for him to do. This experience of the Indian of the Bear clan was incorporated on a pole erected by his nephews by carvings of the uncle's bear totem biting the dorsal fin of a killer whale.

When a totem is crowned with a hat, the number of rings on top of the hat indicate the number of important feasts the owner has given. No clan, or member of a clan, may adopt the totem of another clan with impunity. Once a clan at Sitka (the Luknaxadi) began to use the frog totem which was claimed by the Kiksadi. This was resented by the latter.

A man and his wife of the Kiksadi clan were out fishing one day when they heard a song. They looked for some time before they discovered that it came from a little frog in the stern of their canoe. The frog was cared for by the woman. In this manner the frog became the property of the Kiksadi clan.

The Kakwantan claim that at one time the eagle rendered valuable assistance to a member of the clan who in time turned into an eagle. That is how the eagle (a Haida totem) became the property of the northern Tlingit.

The woodworm is the particular crest of the Ganaxadi since a woman of that clan suckled the legendary woodworm at Tuxikan.

Conventionalism in art designs.—Totem pole art is almost entirely a representation of animals. These representations refer for the most part to the rôle played by certain animals as actors in native myths. To properly understand the carving one must know the story of the myth. Then, to make the totem pole art still more abstruse, the Indian artist has certain rules of procedure which obtain for him the desired results but which make the representations of animals unintelligible to us unless the rules are also known.

He adds certain parts which convention dictates must be added; or he may simplify and represent only what are to him the essential animal parts. As he wishes to represent animals as the ancestors of the family they are shown with human faces revealing only a few animal characteristics.

The moon has a circular, hawklike face, although the raven is often carved holding the moon as a crescent in its beak. In the first instance, the moon is a personified natural object; in the second, the moon is a feature in the mythical life of the raven as a culture hero. The mythical thunderbird who makes lightning by the flash of its eyes and thunder by the flapping of its wings does not differ from the carved representations of the eagle. The context alone must aid in telling what is intended. There is often a cloud hat on the thunderbird, and the beak is longer than that of the eagle, which is short and curved downward.

The curved beak of the hawk is invariably represented as touching the mouth on the underside; the raven, on the contrary, has a long, straight beak. Birds, even when they take human form, may be recognized by the added beak.

The bear is usually carved in a sitting position holding a stick between its paws, Its teeth are prominent and the tongue protrudes from its mouth.

The shark may be recognized, even when represented in human form, by three parallel markings on the cheeks, representing gill

slits. The forehead rises in a triangular-shaped lobe, while the downward curved mouth is drawn back, exposing sharp, triangular teeth. Fish are always distinguished by their fins.

The killer whale is characterized by a blowhole, a large mouth set with teeth, and a large dorsal fin. The sculpin has two spines over the mouth and a continuous dorsal fin.

Animals are indicated by erect ear bosses placed at the top of the head carving. The beaver usually has a stick in its mouth, also holding it between its paws. The large projecting incisor teeth and scaly flat tail are further characteristics. Certain mythical water monsters may take on a variety of forms; they are often difficult to distinguish from animal figures, such as the beaver or the bear, while they are represented as having the body of the killer whale, including gills and dorsal fins.

When carving in the round, the principle of dissection is introduced by the native artist. This is carried out on totem poles and on many other objects. On the sides of the carved object appear parts of the animal totem that are most characteristic arranged as space and requirements as to the use of the object, as a food dish or for some other purpose, permit. An animal in such case appears as though it were split longitudinally, and the two profiles are joined at the front and rear, thus forming head and tail.

Decline of northwest coast Indian art.—In the art of the northwest coast Indian tribes may be distinguished four essential elements or fields of application. First, painting and ornamentation; second, conventional design; third, realistic design; and, fourth, architecture. As it is essentially tribal mythology and clan totems that are represented it becomes no longer a question of a primitive art. The well-developed mythology and totemic lore of the Indian tribes of southeast Alaska indicate a degree of social organization as high as that of the Maya, Inca, and Aztec. The early stages of development must have passed long before the coming of the white man to the North Pacific. His coming, or rather the coming of iron and steel tools, facilitated the production of totemic and mythological carvings for a time and did not interfere with the construction of totemic memorial and mortuary columns. De la Perouse in 1786 found the Tlingit in possession of knives of native copper, and also of soft iron, the latter, no doubt, coming from the trading posts of the interior.

It was only with the coming of the missionary and the substitution of the white man's burial practices for the traditionally native ways that the decline of their totemic art began. When the Indian learned to look at his art through the eyes of the white race, he no longer constructed totemic images after the old fashion, and the decline of

northwest coast art became rapid. Most of the material still extant is now in the possession of large museums in the United States and Europe, and in the hands of private collectors. Very few objects of native art are now to be seen or purchased in southeast Alaska. A few family heirlooms remain in the possession of natives, but that is all. Rotting poles and houses at the various abandoned native towns scattered throughout the archipelago are the sole remainders of the past glory of one of the most highly developed cultures of native America within the limits of its peculiar form of achievement.

A HAIDA WOMAN BASKET WEAVER

The use of the labret has forced the lower lip to protrude so as to effect a distortion of the facial features. This protrusion becomes more marked with age as larger and larger labrets are inserted

A KWAKIUTL CHIEF WITH FRAGMENTARY CORE OF A CEREMONIAL "COPPER" OR SHIELD-LIKE OBJECT OF HIGH FICTITIOUS VALUE

He has probably given away the bulk of the "copper" at a potlatch to make clear that he is very wealthy

A TLINGIT WOMAN FROM THE VILLAGE OF AUK (JUNEAU), ALASKA

Note use of discoidal labret in center of lower lip

THREE HAIDA WOMEN OF KETCHIKAN GARBED IN THEIR CEREMONIAL POTLATCH DANCE BLANKETS FORMERLY USED AT OLD KASAAN

CHILKAT MEN DRESSED IN CEREMONIAL POTLATCH HELMETS AND BLANKETS. THE CHILKAT BLANKET INCORPORATES ONE OF THE MOST PLEASING FORMS OF NATIVE TLINGIT DECORATIVE ART

The extensive weaving of concentric oval or oblong figures in green, yellow, or black colors produces here the same effect as do the concentrically incised designs inscribed on ceremonial objects of wood

BURIAL HOUSES OF THE TINNE INDIANS IN THE CEMETERY BELOW KALTAG, ON THE YUKON RIVER, ARE REMARKABLY LIKE THE NATIVE BURIAL HOUSES OF THE TLINGIT OF SOUTHEAST ALASKA

A TLINGIT DUGOUT CANOE WITH A GROUP OF NATIVES FROM JUNEAU, WHICH APPEARS IN THE DISTANCE

AN OLD VIEW OF THE VILLAGE OF KLUKWAN

The solitary figures at the tops of the poles represent the owners and are unique among decorative carvings on totem poles in southeast Alaska

MEMORIAL COLUMNS AND BURIAL HOUSES IN NATIVE CEMETERY AT KETCHIKAN

The plain columns with carved figurines at bottom and bird figures at top are Tlingit, while the elaborately carved columns near the center are Haida. The two burial houses are essentially native, although latticed pickets at the sides show Russian influence

A NATIVE HOUSE AND TOTEM POLE AT SKIDEGATE, A HAIDA VILLAGE ON THE WEST COAST OF THE QUEEN CHARLOTTE ISLANDS, BRITISH COLUMBIA

Carvings of grizzly bear may be distinguished near top and bottom of the column, while the Raven occupies a place at the center. The house entrance through base of pole has been supplanted with modern doors, and windows have been added

EAGLE HOUSE "HUT-NES" AND TOTEM POLE AT OLD KASAAN, BUILT MANY YEARS AGO BY SANIXAT

Crests carved on pole are: Eagle, at top; beaver, at bottom; bear with protruding tongue, beaver with large projecting upper incisor teeth at center. A frog and a sculpin are carved on pole just above the bottom figure representing the beaver

AN OLD PAINTED HOUSE FRONT OF THE KWAKIUTL INDIANS AT ALERT BAY, VANCOUVER ISLAND, BRITISH COLUMBIA

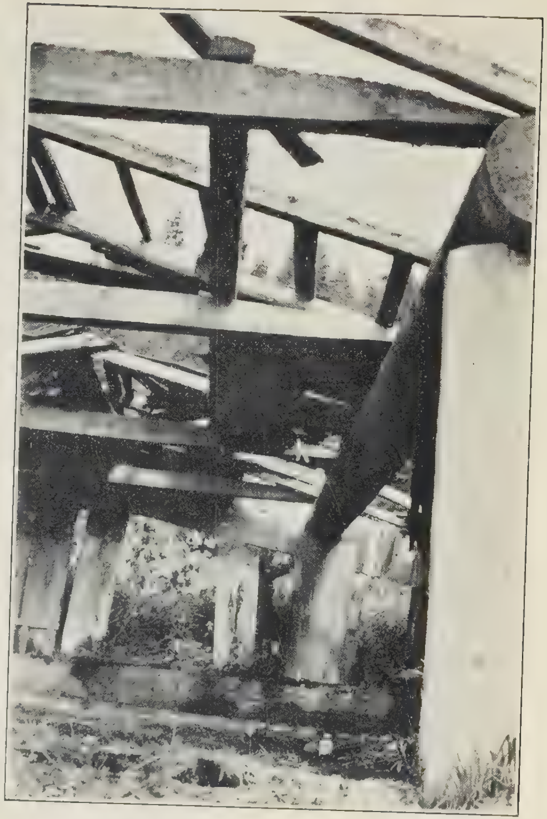
The crest is that of the orca or killer whale

OLACHEN OIL PRESS OPERATED BY A KWAKIUTL INDIAN WOMAN

The oil is deposited in a box underneath the basketry bag oil press

TYPES OF DECORATED REAR-CORNER HOUSE POSTS CARVED BY THE HAIDA. THAT FROM KASAAN (IN CENTER) WAS ERECTED BY CHIEF SKAUL

The carved figures at top and bottom represent the bear, a crest often used by members of the Raven clan. The carved figure at the center of the post has to do with the adventures of "Raven traveling"



A VIEW OF EAGLE HOUSE "HUT-NES," OLD KASAAN, SHOWING DETAIL OF FRAMEWORK AND THE MECHANICS OF CONSTRUCTION OF A NATIVE HAIDA DWELLING HOUSE

A TLINGIT POLE AT TONGAS VILLAGE ILLUSTRATING THE LEGEND OF THE FOG DAUGHTERS

MEMORIAL COLUMN AT OLD KASAAN ERECTED BY NASTAO IN 1877 TO COMMEMORATE A POTLATCH. THE TWO FIGURES WITH HIGH HATS AT TOP OF THE POLE REPRESENT WATCHMEN OF HIGH RANK

The man with the big beard at center top of pole is the "Great-One-on-the-Sea." Beneath this figure is that of an eagle, followed by figures or crests representing the killer whale woman, the killer whale, and a

CARVED FLAT SECTIONS OF CORNER HOUSE POSTS FROM THE HAIDA VILLAGE OF TANU, QUEEN CHARLOTTE ISLANDS. NOW IN THE U. S. NATIONAL MUSEUM

VIEW OF THE CENTRAL SECTION OF THE HAIDA VILLAGE OF OLD KASAAN AS IT APPEARED IN 1900

The large pole in the center of the picture near the flagpole was exhibited at the Universal Exposition at St. Louis in 1904

ALL THAT REMAINS OF OLD KASAAN IN 1927. THE FOREST IS RAPIDLY ENCROACHING

The decorative designs on memorial columns and totem poles are becoming obliterated by the process of rotting, which is practically continuous throughout the year

LIKE SIMILAR POLES AT OLD KASAAN, THIS POLE AT HOWKAN HAS TWO 3-RINGED WATCHERS AT THE TOP

An eagle with conventionalized feathers is at the bottom. The figure at the center with paws in front of its mouth and with tiers of conventionalized feathers shows the influence of the white man's art

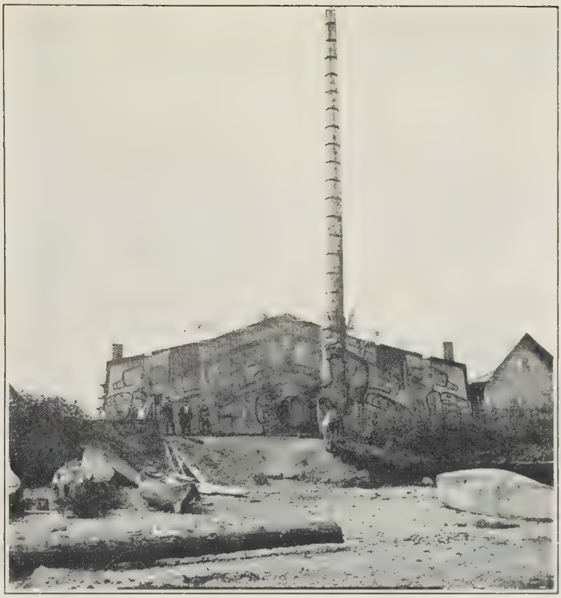
MEMORIAL COLUMNS IN FRONT OF HOUSE OF HEAD CHIEF AT WRANGELL, ALASKA

The grizzly bear on pole to the right is the totemic family crest of the Nanyaanyi clan; the figure on pole on the left is a mythical creature, while the figure serving as a hat for the monster is the killer whale

THE ABANDONED TLINGIT VILLAGE OF "DASAKOK" (SAND-BEACH-AROUND), OR VILLAGE ISLAND, HAS MANY MEMORIAL COLUMNS SHOWING UNUSUAL SEVERITY OF DESIGN AND BARENESS OF OUTLINE, CONTRASTING IN THESE RESPECTS WITH THE MORE INTRICATE AND PLEASING HAIDA DESIGNS

THE MODERN ATHAPASCAN VILLAGE OF CHENEGA, PRINCE WILLIAM SOUND, ALASKA, SHOWS NO TRACE OF THE DECORATIVE ART USUALLY ASCRIBED TO INDIANS OF SOUTHEAST ALASKA

These Indians are newcomers to southeast Alaska and have but recently displaced the Eskimo



A TSIMSHIAN CHIEF'S HOUSE AT PORT SIMPSON, BRITISH COLUMBIA. EACH GROOVED RING IN THE TALL TOTEM POLE REPRESENTS ONE POTLATCH GIVEN BY THE CHIEF

TOTEM POLES IN THE TERRITORIAL PARK AT SITKA, ALASKA

These poles have been carefully preserved against weathering and decay. Native paints have been applied so as to give the poles their original appearance

TYPES OF HAIDA AND TLINGIT TOTEM POLES

The Haida pole at the left had been erected originally at Old Kasaan, was later given by Chief Sanixat to Governor Brady, was exhibited at St. Louis in 1904, and is now in the Territorial Park at Sitka, Alaska. It is supposed to be Alaska's most elaborate column. The other poles were carved by the Tlingit

ESKIMO BURIAL HOUSES AND MEMORIAL COLUMNS AT TOGIAK, ALASKA PENINSULA, ALASKA, ARE SIMILAR TO THOSE OF THE TLINGIT INDIANS OF SOUTHEAST ALASKA

Sculpture of the human figure was formerly practiced by native Americans from California to Bering Sea, but reached its highest development in southeast Alaska and in British Columbia

AN ESKIMO CEMETERY AT TOGIAK, ALASKA

The portrait carving surmounting the memorial column on the left is quite similar to those from southeast Alaska. Copper kettles thrust over the tops of posts on the right are "killed" property. This practice is generally observed by Indians throughout Alaska

THE TLINGIT VILLAGE OF TONGAS

The pole at the extreme right, named "Daylight-asked-for-Raven," is now in Pioneer Square, Seattle, and belonged originally to the Raven people. Pole third from right is surmounted with a carved wooden figure in the likeness of Abraham Lincoln

A SECTION OF OLD KASAAN AS IT APPEARED SHORTLY AFTER IT WAS ABANDONED BY THE HAIDA. THE HOUSE AT THE CENTER IS EAGLE HOUSE, WHICH WAS BUILT BY SANIXAT (SOUTHEAST)

Originally there were no windows nor sawed boards on the front wall. Entrance was gained through a small opening reached by a stairway.

THE INTERPRETATION OF ABORIGINAL MOUNDS BY MEANS OF CREEK INDIAN CUSTOMS

By John R. Swanton

[With 7 plates]

It is well known that when Europeans began settling that part of the territory of our Union now occupied by the Gulf and Central States numerous artificial mounds were discovered, many of them of imposing proportions and considerable antiquity. This latter fact and the rather low esteem in which white pioneers had come to regard the aborigines with whom they were in contact gave rise to a belief that the region had formerly been occupied by a different race, a mysterious people, to whom the name Mound Builders was naturally enough given. This view was stimulated very much by a publication of the noted American botanist, William Bartram, who visited the southeastern parts of North America at the time of the Revolution and wrote an account of his travels which is considered one of our best early works upon this section. The fascination of his style and the atmosphere of mystery which he threw about the earthworks of the region visited combined to give his "Travels," and the theory of the Mound Builders along with it, a wide circulation. But, as we shall presently see, his own writings furnish some of the best arguments in refutation of that hypothesis. That his theory should continue to flourish while his more important facts contradictory of it were overlooked is to be explained partly from the hold which the former had gained upon the popular imagination, but more particularly from a curious accident.

Most of Bartram's data relative to the construction of mounds by tribes of Indians existing in his day was contained in an article contributed to the American Ethnological Society, an organization of which Albert Gallatin and Henry R. Schoolcraft were distinguished members. This paper was prepared for publication in part 1 of the third volume of transactions of the society and the issue was actually struck off in 1853, but after about 25 numbers had been distributed the remaining copies were destroyed by fire. In consequence, few were aware of the existence of the paper in question, which did not,

in fact, receive much attention until the republication of the volume in which it appeared in the year 1909, after the revival of the old society.

Thus the "Mound Builder theory" continued to flourish. It was accepted and defended for a century afterwards by the greater number of antiquarians who touched upon the problem, continuing, indeed, until the intensive work in the mound area undertaken by Cyrus Thomas in the eighties at the instance of Maj. J. W. Powell, founder of the Bureau of American Ethnology. The conclusion reached by Thomas—contrary to the preconceptions with which he had started—was that there was no separate race of Mound Builders and no reason for regarding the people who had built the mounds as other than American Indians.

The above is now, as is well known, the belief of practically all American archeologists, but a problem, or rather a set of problems, remains, namely, to establish a definite linkage of prehistoric mounds with historic tribes.

Certain facts bearing upon this question are now generally admitted by students. One is that the Indians of the Algonquian linguistic family played a very minor part in the construction of mounds. This is because the customs of these people did not involve complex mortuary or ceremonial structures, because the remains in the Mississippi Valley attributable to them are slight and superficial, and because it is clear that their occupancy of areas where mounds occur abundantly is relatively modern. They were a northern people whose ancient home appears to have been about the Great Lakes and northward.

The Iroquoian peoples, most of whom lived in historic times around Lakes Ontario and Erie, and in the St. Lawrence and Susquehanna Valleys, probably moved into these territories in relatively late times, displacing Algonquian peoples. Traces of stockades similar in type to those known to have been occupied by Iroquois, extending southwestward from their lands to the lower Mississippi, are noted by certain archeologists, who believe that these works mark their line of immigration, but the only Iroquoian people to whom any of the more imposing "ceremonial" mounds have been attributed are the Cherokee. According to Mooney, some of these Indians in his time retained definite memories of the construction of mounds for their town houses, and, in fact, certain Cherokee town houses are known to have been built upon artificial mounds, whether or not the Cherokee themselves were responsible for them.

It is, however, the remaining groups of Indians, those of the Siouan, Muskhogean, and Uchean linguistic stocks and some smaller bodies—the languages of all of whom show significant structural similarities—with which the mounds must be most closely connected.

The problem of the mounds does not, it should be said, involve all works in the area under consideration, since fortifications, even those as extensive as Fort Ancient, Ohio, may have been the work of almost any people in the territory in question, provided only that they were sufficiently numerous. Stockades reinforced with earth are reported from the entire area. Nor is it a question of burial mounds, because interments of the kind called for were the rule among the Choctaw and some eastern Siouan tribes.

A group of mounds of peculiar character is that including the so-called "effigy mounds," which are characteristic of Wisconsin. A. B. Stout and Paul Radin were informed by Indians of the Siouan Winnebago Tribe living in that region that these had been put up by their own people to mark clan residences and clan lands, but other archeologists have called attention to the fact that the physical type of the people whose skeletons have been disinterred from these mounds is altogether different from that of the Winnebago. The matter is therefore still involved in doubt.

The main problem revolves about the considerable groups of mounds and inclosures which clearly point to the existence of sacred edifices or at least structures of tribal significance. One undoubted reason for the erection of mounds was to raise the buildings they carried out of the reach of floods, but while this will account for the mounds themselves it will not account for the distinction given to certain buildings by the size and height of the mounds on which they stood, or for the shapes of the courts or plazas which usually occur between them, or for the earthworks in the Ohio Valley in circles, squares, and other geometrical patterns. These things point clearly to communal undertakings for communal ends.

Mounds and grounds of this type are, in fact, known to have been in use among the tribes of the Gulf area when Europeans first entered it. At Ucita, the town on Tampa Bay near which De Soto landed his army, the chief's house was raised on a high artificial mound, and buildings placed upon such elevations were frequently encountered by his army. Garcilasso de La Vega describes the construction of a typical mound with some care. He is usually guilty of exaggeration, but there are enough references by other chroniclers of the De Soto expedition to make it clear that mounds were frequently met with in the towns visited and that the chroniclers believed that they had been raised by the Indians found in occupancy. Some of the buildings which they observed upon these mounds are called houses of the chiefs and some temples, but the chief's house in this section often served a semipublic function. When the French visited the Natchez towns near the present city of Natchez, Miss., they found the great temple raised upon an artificial mound and the house of the

chief on another facing it. The Tunica temple was on a mound which also seems to have been artificial. A little later the English trader Adair tells us that the town houses of the Chickasaw and their neighbors, used both for ceremonial and social purposes, were ordinarily raised upon mounds. Mention has already been made of such mounds among the Cherokee.

We now come to the testimony furnished by Bartram, to which reference has already been made. We know, both from the writings of eighteenth century explorers and the perpetuation of the institutions until recent times, that Creek ceremonial grounds consisted of three elements: (1) The tcokofa or "hot house," a circular structure with a central supporting post or cluster of posts; (2) the "square ground," consisting typically of four narrow cabins open in front and occupying the sides of a square, whence the name; and (3) an open, flat space, round or rectangular in outline, with a single ball post in the middle, and, anciently, two slave posts where those who had been captured in war were burned. This last was known to traders as the "chunk yard," evidently because the so-called chunkey game was anciently played in it, but it also had a place in the native ceremonies. It was surrounded by one or more banks of earth formed by periodical cleaning of the ground, when all grass and weeds were scrupulously removed. A similar cleaning was extended to the square ground and the space in which stood the tcokofa. In time these ridges of trash became large and conspicuous and might be taken for low defense works if it were not for the wholly unstrategic positions most of the ceremonial grounds occupied. I have seen one or two ridges about 2 feet high, but most of the modern grounds are so new and comparatively so little used that this ridge is scarcely noticeable. At the Tukabahchee ground there was an additional mound, a few feet in height, heaped together a short distance north (or northeast) of the square. There the bison dance was performed, and it seems to have taken the place of the single ball post which was not within the ceremonial grounds. Such a mound seems to have been a regular accompaniment of the Tukabahchee sacred ground; it was used at least as far back as the time of their first settlement in Oklahoma.

From what Bartram tells us it appears that these mounds and ridges were but vestiges of a much more extensive series of earthworks. In his paper written for the American Ethnological Society he gives three plans of Creek grounds. One of these (fig. 1) shows the arrangement and position in the town common in his time, i. e., about 1778. Another (fig. 2) exhibits the same in more detail. Besides these, he furnishes us with the plan of a square such as was said to be usual at a still earlier period. This is reproduced in Figure 3, from which it will be seen that the chunk yard was in the

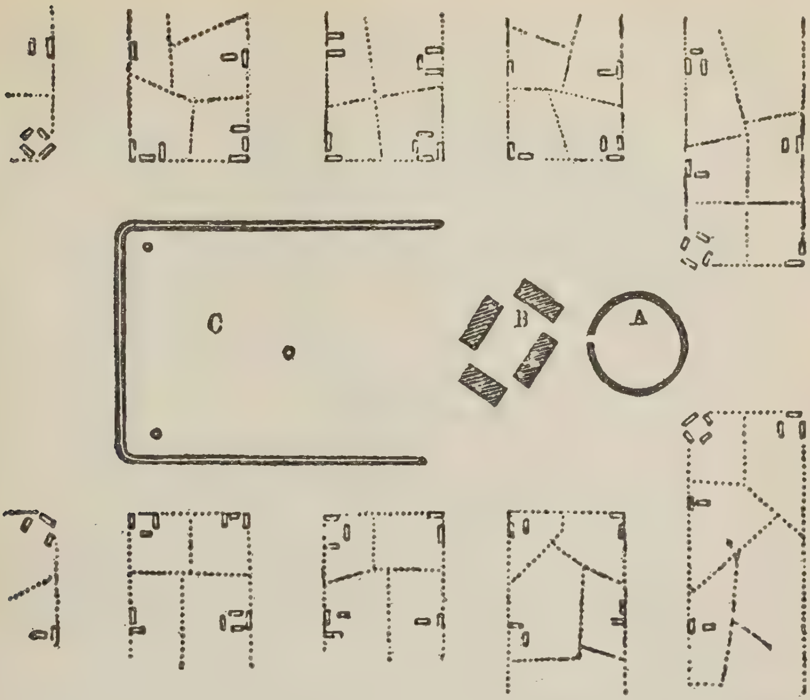


FIG. 1.—Creek ceremonial grounds and their typical position in the town during the latter part of the eighteenth century. (After Bartram)

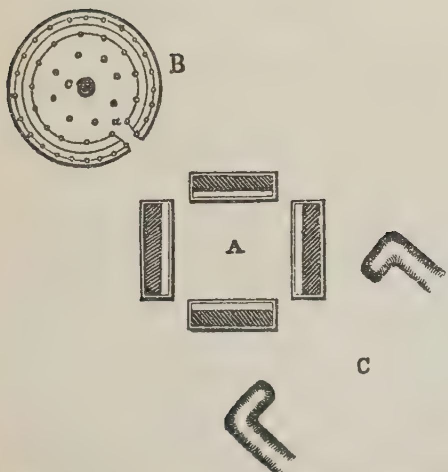


FIG. 2.—Plan of Creek ceremonial grounds of the later type. (After Bartram)

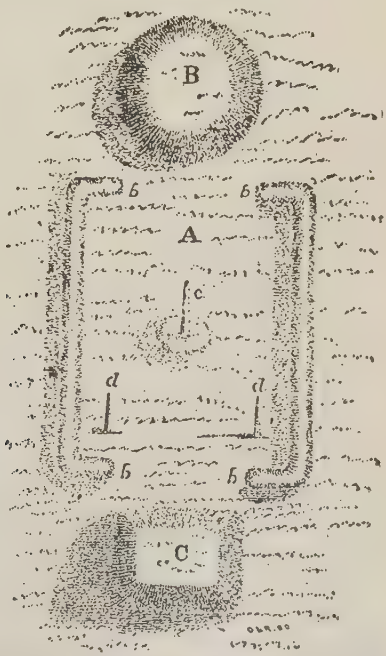


FIG. 3.—Ancient arrangement of Creek ceremonial grounds. (After Bartram)

center, between the tcokofa and the square, and that each of these latter was upon a mound. I do not doubt that this represents an ancient pattern, and at one time it may have been the prevailing one, but it is improbable that there ever was one standard arrangement. Even in the attenuated square grounds which we find to-day there is considerable variation in the number and placing of the cabins or "beds," and in the assignment of these to the various orders of officials. It is worthy of note that while in most squares the cabins lie toward the four cardinal points, at Tukabahchee it is the entrances which are so placed.

The following figures will illustrate the two points just made—(1) the diversity in the arrangement of the squares, and (2) the appearance of mounds connected with them. The original exposures were all made in 1912. It should be premised that normally one of the four cabins was occupied by the Mikagi, or chiefs, another by the Henihas, or second men, a third by the Warriors, including the Tastanagis and Imathlas, and a fourth by the Tasikayas, the initiate warriors, or youths. Plate 1, A, is Alabama square ground as seen from the southeast, a square belonging to one of the formerly independent tribes incorporated into the Creek Confederation. It has but two cabins and these face each other, the one on the east, the nearer in the picture, being that of the Mikagi. The other two cabins are represented by single split logs, both of which may be seen in the illustration. Plate 1, B, is Wiogufki, which, like the Abihka ground and some others, omits the north cabin. The cabin of the Mikagi is in its normal position on the west side of the square. Plate 2, A, is Pakan Tallahassee, which has cabins north, west, and south, but none toward the east. The omission of the east cabin is fairly common, that being the one ordinarily held in least esteem, but Pakan Tallahassee is peculiar in having the chiefs' cabin on the north.

It will be noticed that in this ground and the last the chunk yard and ball post are in the same direction as the missing cabin. Plate 2, B, is Upper Eufaula, where there are again three cabins, but the one wanting is this time that to the west. The chiefs' cabin is north, as was the case in the square last considered, but the ball post is south. Plate 3, A, shows Tukabahchee square, or, rather, the northern part of it, as seen from the west. All four cabins are preserved, and they are larger than in any other late ground, but the accompanying illustration shows only the warriors' cabin and the youths' cabin. It will be remembered that in this town the entrances lie toward the four cardinal points and hence the cabins are oriented halfway. In the squares hitherto illustrated the trash piles are too small to attract attention, but here, while the ridge of trash can not be distinguished easily, it may yet be made out extending around and beyond the tree

in the background. The mound heaped up for the bison dance is, however, readily distinguishable to the left. Figure 4 is a plan of the older Tukabahchee square, now abandoned, showing the general arrangement, the marginal ridge of sweepings, the position of the old tcokofa, and the mound for the bison dance. Plate 3, B, is a view—a rather poor one, unfortunately—of the last-mentioned mound.

In spite of the variation in form shown by the squares, the common position of the elements in later times was with the tcokofa northwest of the square and the chunk yard east of it. In attempting to find mound groups comparable to the ceremonial grounds of the Creek Indians this must be kept in mind, though we should be warned by Bartram's figure of the "earlier" system that more than one was in use. Suggestions among the mounds of the kind indicated are, it must be admitted, slight, but they are not entirely wanting. First, let us examine the plan of a former fortified Indian town in central Tennessee—the earthworks of which were explored by the late William E. Myer and called by him the Gordon Group (fig. 5). Most of the space inside the line of the old stockade is occupied by small rings of earth, the former sites of dwellings. In the center, however, we have a rather larger ring, roughly oval in shape, with a small mound east of it and beyond an open space or plaza. The last might well have been the chunk yard of this town with the square near its western end, while the larger oval occupies the very site where the tcokofa should stand. The small mound I am unable to explain.

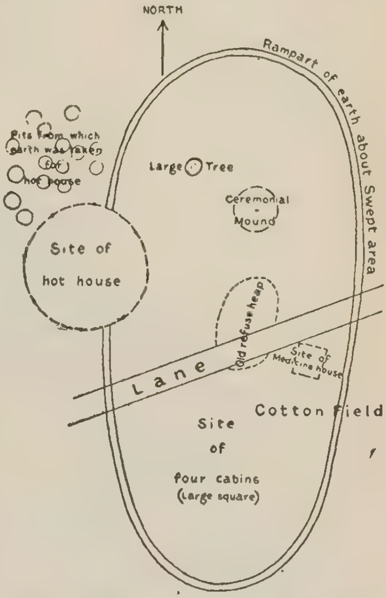


FIG. 4.—Plan of the old Tukabahchee square ground in Oklahoma

Other mound groups do not exhibit such close similarities and they are rather of Bartram's older type of square, open spaces with mounds east and west of them and sometimes also north and south. Plate 4, A, is the mound group at Selsertown, Adams County, Miss., interesting as being in the country of the Natchez Indians. Plate 4, B, shows a mound group at Prairie Jefferson, Moorehouse Parish, La., taken from Squier and Davis. Figure 6 is the Taylor Shanty

group, Poinsett, Ark., which, like Plate 4, A, is taken from Thomas's report. Figure 7 shows the mounds which once stood on the site of St. Louis, Mo., as given by Bushnell. Plate 5, again from Squier and Davis, is introduced to show the juxtaposition of squares and circles, recalling the association in Creek grounds of the squares and the circular spaces in which the tcokofa and sometimes the ball post

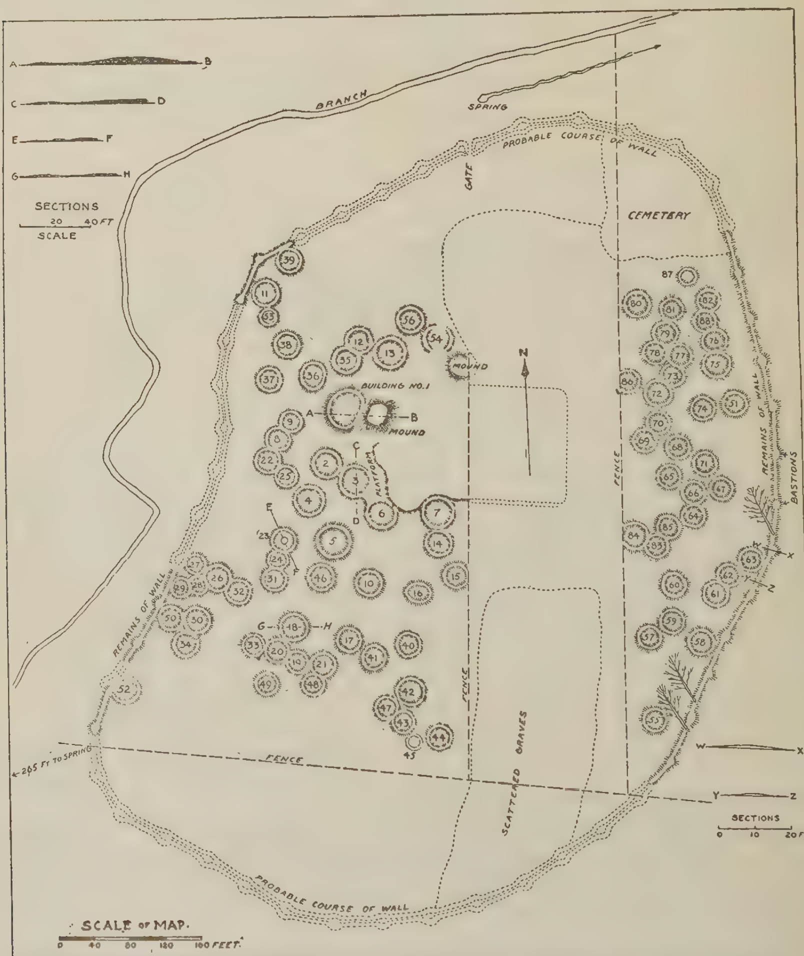


FIG. 5.—Plan of the Gordon group of mounds, central Tennessee. (By W. E. Myer)

are placed. The mounds represented are in the neighborhood of Chillicothe, Ohio. These are much larger than the corresponding Creek elements, but it is not impossible that in former days structures like the Creek square and tcokofa may have been surrounded by fortifications or by ridges of rakings similar to the ridges of trash about Creek grounds, but at greater distances. Finally I introduce a plan

of the greatest prehistoric city of the eastern United States, Cahokia (fig. 8), to show that it is not impossible to suggest an origin for this in an extension of the cultural tendencies which we have been tracing. There are open spaces in two spots, but the resemblance between this collection of mounds and the Creek ceremonial group as known to us historically is admittedly distant. However, it has not been my

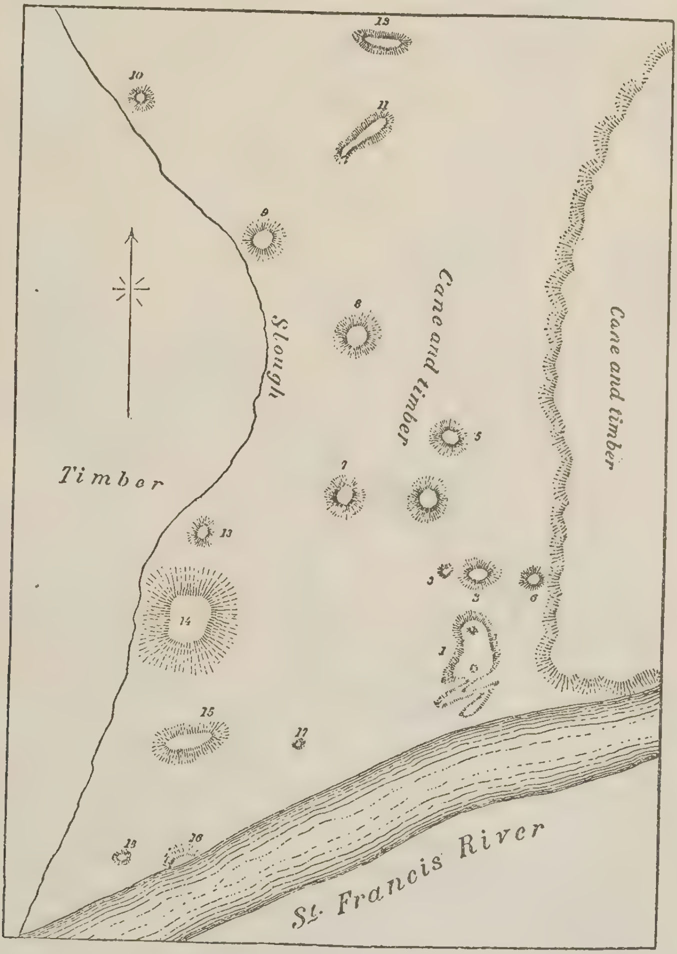


FIG. 6.—The Taylor Shanty group of mounds, Poinsett County, Ark. (After Thomas)

object to prove that all of the great mound groups of the Mississippi Valley were Creek or even Creek with variations, but to show that the known ceremonial grounds of the Creeks are of the same genus, if not of the same species, as the mounds which date from prehistoric times.

One obstacle to the acceptance of an identification of the mound builders and the Indians has been the assumption that striking cere-

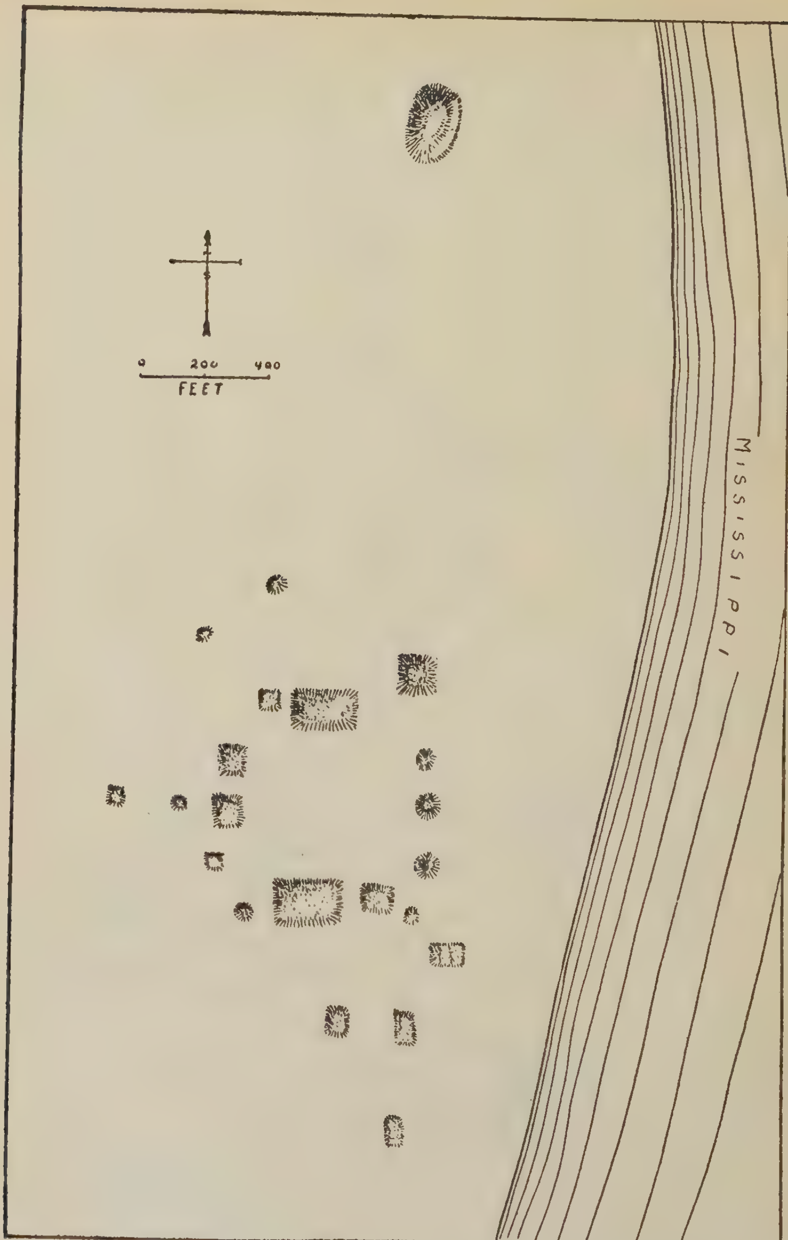


FIG. 7.—Former group of mounds at St. Louis, Mo. (After Bushnell)

monial grounds and imposing mounds like those of Cahokia or Nanih-waiya (pls. 6 and 7) presuppose advanced religious beliefs and a much more elaborate ritual than any thought to have been in existence among the tribes found in the region. A few early writers,

like Du Pratz and Adair, have spoken of ceremonies as monthly occurrences, but in such general terms that little importance could be attached to their remarks. The "green corn dance" was often mentioned but the name was applied to very diverse ceremonies, many of them of the simplest character, so that little is signified by it.

Among the Creek Indians, however, the term "green corn dance" applies specifically to the busk, or poskita, meaning the "fast," which occurred when the first flour corn of the season was ready for

FIG. 8.—Mound group at Cahokia, Ill. (After Bushnell)

consumption, between the middle of July and the middle of August. In the course of my investigations among these Indians, about 15 years ago, I learned that the busk was not an isolated ceremony. It was the most important ceremony of the year, that indeed with which the new year began, but it was the fourth of a series of rituals spaced a month apart and, hence, beginning in April or May. The first three were rather local in character and prepared the way for the main ceremonial to which many persons of related and friendly towns were invited. Following the busk, particularly if food were plenti-

ful, came a succession of social gatherings extending into the late fall and ending with a ceremony called the "raccoon dance," or "the old people's dance," the only one in which masks were worn. One Creek informant declared this to have been the most sacred ceremonial of all. The religious side of some of these dances was not always conspicuous, but we know of them only in their decadence and it seems to be a universal truth that when ceremonies decay, the social elements become progressively more pronounced, while those having esoteric or sacred import are gradually abbreviated. As far back as the middle of the eighteenth century Adair observed this process taking place. There are, then, so far as the Creek Indians are concerned, good indications of a long summer ceremonial season, and it would have taken comparatively little elaboration of the known rituals to produce a pageant intricate and imposing enough to match any mound group of which we have knowledge, even Cahokia itself.

We may conclude, then, by saying that the historic ceremonies and ceremonial mounds of our southeastern Indians, or, for that matter, of the Creeks alone, suggest psychical and technical forces sufficient to account for all of the mounds of the Mississippi Valley and the districts north of the Gulf of Mexico. Certain sections of the region in question, particularly the Ohio Valley, had unquestionably been abandoned by mound-making peoples when the whites entered it, but that abandonment was evidently due to a shift southward of the Muskhogean and other related peoples or the emigration of Siouan Tribes southeast and northwest, a movement possibly initiated by the invasion of the Iroquois and their relatives from some region in the west.

A.—SQUARE GROUND OF THE ALABAMA INDIANS OF THE CREEK CONFEDERACY, FROM THE SOUTHEAST

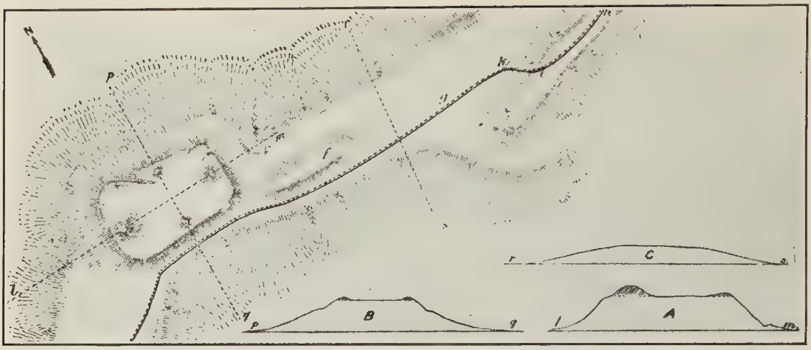
B.—SQUARE GROUND OF THE WIOGUFKI INDIANS, CREEK CONFEDERACY, FROM THE SOUTHWEST

A.—SQUARE GROUND OF THE PAKAN TALLAHASSEE INDIANS, CREEK CONFEDERACY, FROM THE WEST

B. SQUARE GROUND OF THE UPPER EUFAULA INDIANS, CREEK CONFEDERACY, FROM THE SOUTHWEST

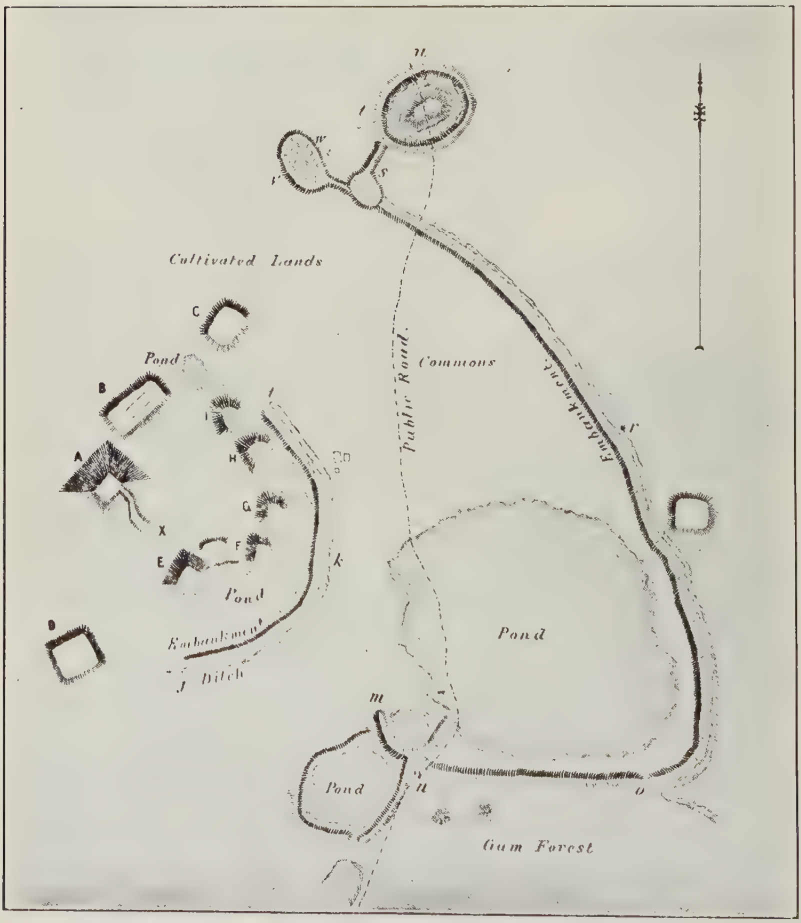
A.—SQUARE GROUND OF THE TUKABAHCHEE INDIANS, CREEK CONFEDERACY, FROM THE WEST

B.—MOUND WHERE THE BISON DANCE WAS HELD AT THE OLD TUKABAHCHEE SQUARE GROUND



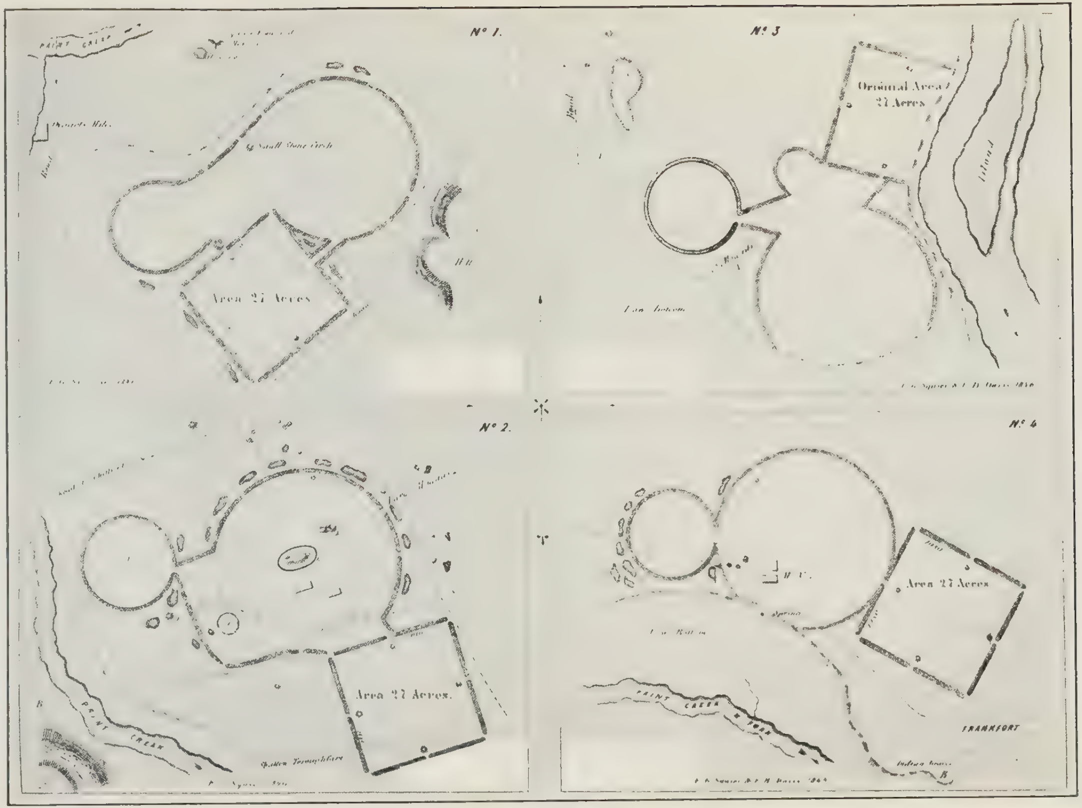
A.—MOUND GROUP AT SELSERTOWN, ADAMS COUNTY, MISS.

(After Thomas)



B.—MOUND GROUP AT PRAIRIE JEFFERSON, MOOREHOUSE PARISH, LA.

(After Squier and Davis)



MOUNDS IN THE NEIGHBORHOOD OF CHILLICOTHE, OHIO

(After Squier and Davis)

THE GREAT MOUND AT CAHOKIA

(After Bushnell)

THE NANIH-WAIYA MOUND, WINSTON COUNTY, MISS.

FRIEDRICH KURZ, ARTIST-EXPLORER

By David I. Bushnell, Jr.

[With 8 plates]

Friedrich Kurz was born in Bern, Switzerland, January 8, 1818, and died there in 1871. He possessed much natural talent and the beauties of nature, "the primeval forest and Indians had an indescribable charm" for him. He planned to visit a country where he could find life in a primitive state, and consequently, in 1839, at the age of 21, decided to go to Mexico. He consulted his friend Karl Bodmer who had recently returned from America with Maximilian, and was advised to become more proficient "in the drawing of natural objects and in the true representation of animals." He therefore remained in Europe and devoted much time to study. He went to Paris where he worked earnestly and made trips to other parts of France to sketch and paint. And not until the autumn of 1846 did he leave Bern and travel to Havre where he secured passage on the *Tallahassee* for New Orleans.[1]

The *Tallahassee* reached New Orleans December 24, 1846, at a time when there was great excitement about the war with Mexico. On New Year's Day of 1847 Kurz started up the Mississippi to St. Louis on the *Amaranth* and after a very unpleasant trip, with long delays caused by drifting ice, arrived at his destination January 17, 1847. While there, on February 15, he witnessed a parade in celebration of the eighty-third anniversary of the founding of the city. During the following months, before beginning his long journey up the Missouri, he made several trips up and down the Mississippi. Thus on March 24 he went up the Mississippi to Nauvoo, when he became interested in the Mormon question, but soon returned to St. Louis on the *Laclede* and wrote "that steamer and the *Tempest* were the

[1] During a visit to the Historical Museum, Bern, Switzerland, in 1906, I was shown the manuscript journal written by Kurz while in America, 1846–1852. With the journal was the sketchbook carried by him in the upper Missouri Valley. Later in the season I arranged to have a copy of the journal made, and also photographed the greater part of the sketchbook. This copy of the original manuscript and photographs of the sketches are now in the Bureau of American Ethnology, Smithsonian Institution, and form the basis of the present article.

best equipped boats on the upper Mississippi." He again went up the Mississippi during the latter part of May on the river boat *Providence*, and when a short distance beyond Rock Island there was a disastrous explosion on the boat "as so frequently occur on North American steamers." The survivors went on board the *Red Wing* and continued on to Galena. They passed the rapids and Kurz wrote in his journal:

When shall I ever forget Rock Island and that group of, apparently, cold-blooded Fox Indians who wrapped themselves so snugly in their blankets and watched us with such curiosity?

He returned to St. Louis on the *War Eagle*. On November 19 he left St. Louis for New Orleans. And "on that visit," so he wrote, "I saw many Choctaws at the market. The men were selling wild game, rabbits, turkeys, venison, and the women were selling seeds, grain, and healing herbs." He again started up the Mississippi, this time on the *Hannibal*. There was much ice in the river and the *Hannibal* did not proceed above the mouth of the Ohio; therefore it was necessary to go aboard the *Oswego*, coming from Louisville, but near Chester, Ill., the latter "stuck fast again." Here Kurz and his companions went aboard the *Boreas No. 3*, a small craft which landed them at St. Louis December 24, 1847, just 14 days after they had left New Orleans.

Kurz had decided not to go to Mexico, as first planned, but to traverse the region previously visited by his friend Bodmer. Consequently on April 5, 1848, he left St. Louis on the *Tamerlane* bound up the Missouri. He reached St. Joseph April 18, and then began his studies of the Indians and of ways of life in the Indian country. To quote from his journal:

St. Joseph, once the trading post of Joseph Robidoux, is situated at the foot of the Black Snake Hills on the left bank of the Missouri. Though the town was founded only six years ago, there are evidences of a rapidly expanding city. * * * Indians of various tribes—the Pottowatomies, Foxes, Kickapoos, Iowas, and Otoes—one sees constantly in this town, particularly at the landing where they take the ferry to cross the river. * * * Throughout the entire summer bourgeoise, or the heads of firms, clerks, and other engagees or employees of the different fur companies crowded the streets and public houses of the town. St. Joseph is for them now what St. Louis was formerly—their rendezvous.

Soon after reaching St. Joseph, with its ever changing population, Kurz began to recognize the members of different tribes and to be able to distinguish their characteristics. He wrote:

After a more extended acquaintance with the various tribes one becomes observant and notices their definite marks of distinction. For instance, the Pottowatomies' skin is much darker than that of other tribes of this region,

their features less noble, their bearing not so stately. They wear their hair loose and unkempt. The men are usually fully clothed. They wear, usually, a coat and leggings of tanned deerskin, the leggings having a broad, double-projecting seam that distinguishes the wearer from members of any other tribe. Frequently they wind around their heads and loins woolen scarfs or sashes that are embroidered with beads in a design of arrowheads in different colors called, therefore, *ceinture á fleche.*

He then continued by referring briefly to the customs of the Iowa, with whom he was in daily intercourse. To again quote:

The Iowas are a more cleanly people than the Pottowatomies; they are also of a brighter color, handsomer and more stately in bearing. The men stiffen their hair with grease or loam and wear it pulled back from the forehead in such a way that the brow, being entirely exposed, appears very high. They do not wear the shirt of deerskin nor do their leggings have the broad-projecting seam, but the latter are often trimmed with beads. On the whole they wear very little clothing in midsummer; with the exception of breech cloth and blanket, they wear no clothes at all.

The peculiar manner of preparing their hair, as just mentioned, is clearly shown in several sketches which are now reproduced. Kurz appears to have been quite interested in the various ways of arranging the hair, as followed by the several tribes. He wrote regarding the Sac and Fox:

They shave the hair entirely from the crown of their heads and arrange what is left at the back in such a way that it looks like a tuft or brush. Some of them leave the long hair on their crowns for a support on which to fasten their head ornaments. The braves have a proud war-like mien.

Kurz remained at St. Joseph during the winter, often making trips into the adjacent country.

In the late autumn of 1848 the Missouri froze over to such a depth that a four-horse team, or sleighs laden with wood, could cross without the slightest danger.

About that time a band of Iowa Indians encamped near the bank of the Missouri just across from St. Joseph. There were some 30 families, and Kirutsche was the chief. Kurz crossed the river on the ice during the evening of December 15. He wrote in his narrative:

As I was crossing the frozen stream an ice-cold wind swept across the river, driving before it a cloud of snowflakes. In the forest I found many converging paths and did not know which one would lead to Kirutsche's tent. As soon, however, as I was well into the wood, out of the howling wind, I heard the measured beating of a drum. Following in the direction of that sound I arrived in a short time at a wigwam. I had expected to find a tent of skins similar to those I had already passed, but this was a hut constructed of withes in elliptical form and overarched with rush mats. At the top was an opening for light and for the egress of smoke, and cut low in one of the long side walls was another that served for door. The latter was covered, as by a curtain, with an animal pelt.

Later Kurz again referred to the habitations in the Iowa camp and stated:

The tents were, for the most part, conical in form and made of skins in the usual Indian fashion. There were among them, however, some wigwams constructed of osier twigs or withes and covered with rush mats. There were others constructed with pieces of bark with a roof of the same material—that is, with strips of bark laid across the top. The last form of hut could be used only when roof and sides were covered with snow.

The Iowa village proved an interesting place. Kurz was much surprised to hear some of the younger Indians speak very good English.

I asked Uotschetsche, one of the young men, whether they taught so well at the mission. He said not so, but at Johnson's school in Kentucky. That man Johnson appears to be a great friend to the Indians.

And again referring to the Iowa:

Their attitudes and movements are never awkward. Their hands, which are perfectly flexible and supple from their constant practice in the sign language, they use in a manner particularly graceful.

The games played by the Indians always proved of interest to the young artist. Some weeks after leaving the Iowas, while at Fort Union, on the banks of the upper Missouri above the mouth of the Yellowstone, he wrote:

The Iowas are fond of card games, but on many occasions I have seen two young people sit down on the ground opposite each other, take off their moccasins and place all four in a row between them. Then one of the players thrusts his hand into each moccasin, leaving in one of them some small object. His opponent has now to guess in which it is to be found. He is allowed only one chance. If he guesses correctly he wins the game, if not he loses.

About the end of January, 1849, "the first gold seeker showed himself in St. Joseph." The Missouri was open to navigation about the middle of February when "several thousand of those adventurers, all in a heat from gold fever, streamed into St. Joseph." Kurz then told of the wild rush to California, the curious crowds that gathered to cross the Missouri, the troubles and disappointments of many. About June "the Mormons assembled near Kanesville, 8 miles from Council Bluffs, in readiness to wander on to Salt Lake and found their new Zion." The year passed without much of interest having been accomplished by the artist who, however, had been quite ill but had fully recovered. Nor was the year 1850 of any greater interest.

On May 11, 1851, Kurz left St. Joseph on the river boat *Sacramento* for Council Bluffs where, so he wrote in his journal:

I shall wait for one of the two boats that make annual trips to the Yellowstone in the interest of the two fur companies and bring back the commodities that supply their traffic.

The following afternoon they "passed a community of Otoes and various settlements of half-breeds," and late on May 13 arrived "at Iowa Point near the Bluffs."

Kurz was ever anxious to visit new places. The day after reaching Council Bluffs, he crossed the Missouri to Belle Vue, Peter A. Sarpy's "trading house for the Omahaws." On the river a short distance below Sarpy's house was—

a Protestant mission, and beyond MacKinney a trading place for the Otoes and Omahaws, a beautiful far-reaching view over the estuary of the Big Platte.

While in Belle Vue, on May 16, Kurz saw for the first time an earth lodge, and at that time made a sketch of a Pawnee girl near one of the lodges. May 20 proved an interesting day for Kurz, and to again quote from his journal:

Crossed again to Belle Vue for the purpose of visiting a village of Omahaws 6 miles distant.

He followed a path over the hills, then traversed a wooded plain and soon reached the banks of Papillon Creek, beyond which, on elevated ground, stood the Omaha village. The village was rather small but probably characteristic of many throughout the region. As described by Kurz:

Their dwellings consisted both of skin tents and clay huts in the midst of which were scaffolds used for the curing of meat and high inclosures in which they confined their horses for safety. On the side from which I entered the village there was a narrow ditch or trench, whether constructed for defense—a shelter behind which they fired on their enemies—I do not know. They mounted the meat scaffolds by means of the simplest sort of improvised ladders—the trunk of a tree about 6 inches in diameter in which steps were cut. I took a walk about the village. For a long while I watched the sport of the young boys, as they practiced hurling the spear with great velocity through a rolling brass ring. Before a clay hut sat the personages of the village as spectators and judges, some of them distinguished by their trappings.

Kurz made many drawings during his stay at Council Bluffs and when visiting in the surrounding country, some of which are now reproduced.

On June 1 Kurz was invited by Peter A. Sarpy to remain with him at Belle Vue until the arrival of the boat in which he was to proceed up the Missouri. Three days later, on June 4, Kurz entered in his journal:

I am living in a trading house; I sleep on a buffalo robe; I am again in the midst of Indians, who are continually trading with Mr. Sarpy. He lets them have gunpowder, lead, and tobacco on credit, that they may prepare for hunting during the summer. Buffalo range about 80 miles from this village. Stephen Decatur, a nephew of the celebrated commodore, is employed here now as clerk. He was formerly a teacher in the East. There are three other

employees: Joseph La Flesche, Sagan Fontanelle, and Peter, an interpreter for the Omahaws and Otoes.

Kurz was ever interested in the details of Indian dress, and wrote at that time:

The Omahaws wear moccasins made of elk skin blackened with smoke and usually with an ornamental seam across the back of the foot. The flaps turn outward.

These were very eventful days for the artist. Every hour presented something new or exciting.

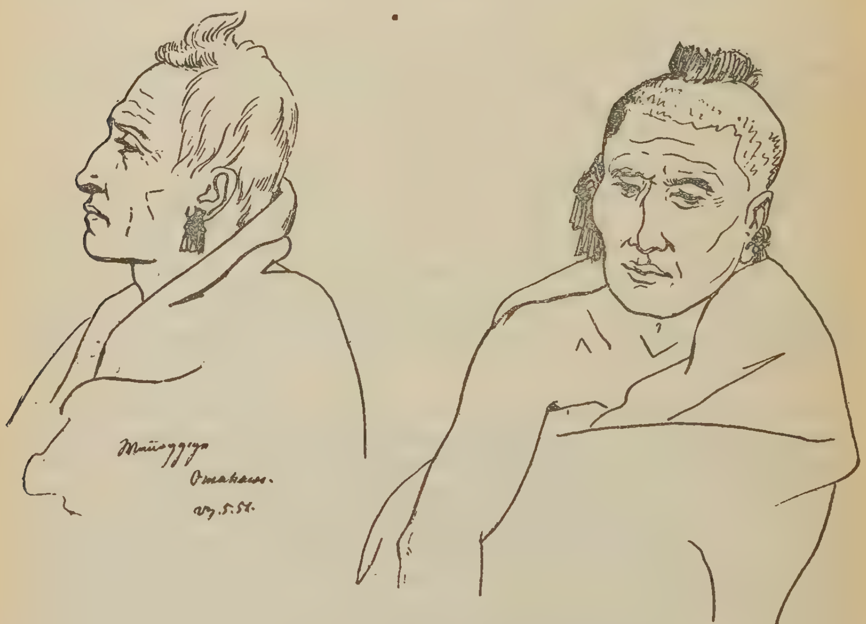


FIG. 1.—Omaha. Managgiga. May 23, 1851

On June 10:

Just as I was beginning a portrait of an Omahaw youth three gentlemen came in, two of whom, W. Picotte and A. Culbertson, I knew already. They are agents in the upper Missouri region for the great fur trading company.

Kurz told of his desire to visit the far upper waters of the Missouri.

The preceding day, while at Belle Vue, he had made several sketches of Omaha Indians. One was "a portrait sketch of Waascha-mani, a very old former chief of the Omahaws."

Two days later, on June 12, Kurz rode with Joseph La Flesche to the Omaha village beyond Papillon Creek to witness a dance around Tecumseh Fontanelle, who had accidentally shot himself a few days

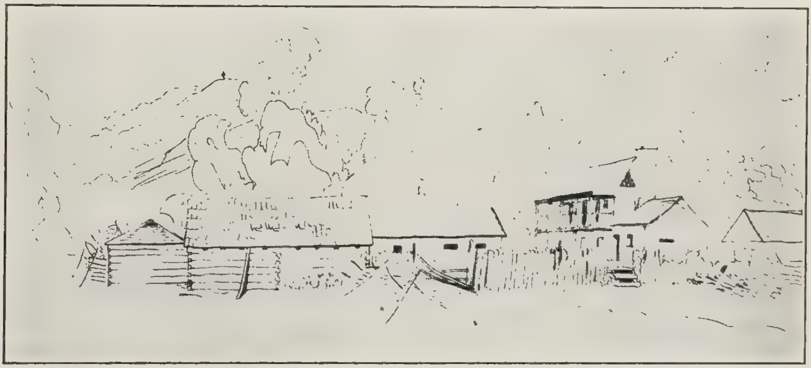
1.—FRIEDRICH KURZ AND IOWA INDIANS

2.—IOWA INDIAN. DECEMBER 19, 1850

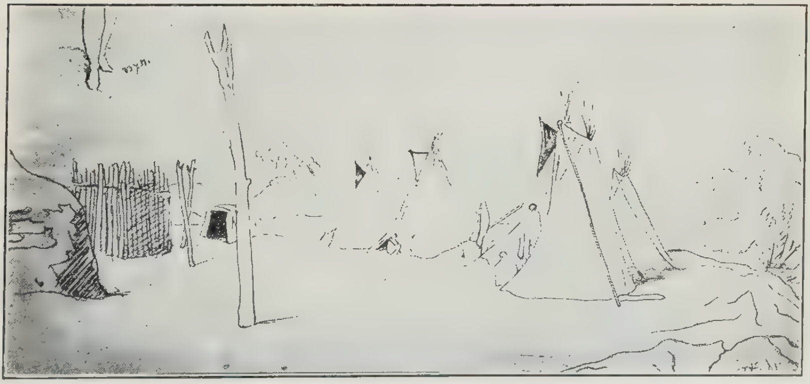
1.—POTAWATOMI. MAY 21, 1851

2.—OMAHA. ON LEFT, CHIEF YOUNG ELK. MAY 23, 1851

1.—OTO. GROUP WITH A CANOE. MAY 15, 1851



2.—SARPY'S "TRADING HOUSE FOR THE OMAHAWS." MAY 16, 1851



3.—OMAHA VILLAGE. MAY 20, 1851

1.—THE "ST. ANGE." JULY 2, 1851

2.—"CALIFORNIANS AT COUNCIL BLUFFS." MAY 12, 1851

before, evidently while at Sarpy's trading house. Kurz wrote in his journal:

> The dance of the buffalo troop was held in a large, roomy clay hut. Ten dancers arranged in pairs imitated in the most natural manner the way that buffalo drink, the way they wallow, how they jostle and horn one another, how they bellow, and all the while the performers sprinkle the wounded man with water. All the dancers wore decorated buffalo masks and buffalo tails fastened to their belts in the back. With the exception of the never-failing breech-cloth they were otherwise nude. A throng of people looked on. Only the Yonglens, or Indian doctor, danced alone and without mask and tail.

A wild scene, and it is to be regretted that Kurz did not describe it more in detail, but he continued and mentioned the people themselves:

> The Omahaws have suffered so dreadfully from attacks of illness and from the Sioux that they could gather hardly 80 warriors. At present they are exiles from their own territory and live on lands belonging to the Otoes.

Kurz had now been away from St. Louis more than three years. He had seen Indian life on the border and was about to set out for the upper Missouri Valley. Where and how far he would travel he did not know. He had no plans to guide his movements. But the year following his departure for the waters of the upper Missouri proved the most interesting period of his stay in America. While at Fort Berthold, and later at Fort Union, he made numerous drawings, and in his journal—brief quotations from which will follow—recorded many events and described the customs of those who frequented or lived at the posts. And he was enabled to study and sketch the wild animals of the region in their natural environments, as had been his great desire.

THE UPPER MISSOURI VALLEY

Monday, June 16, 1851, "the company's boat" *St. Ange* arrived at Sarpy's trading house. It made a short stop, Kurz went aboard, and was soon bound up the Missouri. It was a sad and dangerous journey, and the first day he wrote in his journal:

> The steamer is really a hospital for victims of cholera, the sick, and the dying! My cabin is filled with effects of people who have died.

And the next day:

> No doctor on board, two more deaths since yesterday! Evans, a professor in geology, prepared the remedy—meal mixed with whisky—that I administer. Father Van Hocken bestows spiritual consolation. Father de Smet is not well, but he is not suffering from cholera.

June 19:

> In the evening we were forced by a violent tempest to lay to near Black Bird's grave. Such raging wind! Such a flood of rain! Such vivid lightning!

The following day they remained where they were—

to air clothes in the sunshine, to take better care of the sick, and to bury the dead.

June 21:

Pere Hocken dead. He died as a Christian. Had been sick only two hours. It was about 4 o'clock in the morning when I heard him calling me. I found him half dressed, on his bed, in violent convulsions. I called Pere de Smet. We anchored in the evening and buried him by torchlight. Pere Hocken was to have gone as missionary to the Nezperces. And I had not sketched his portrait for Pere de Smet.

Thus, the *St. Ange*, with death and suffering aboard, continued its voyage up the Missouri, and on July 4, so wrote Kurz:

While we were at an extra lunch in honor of the Fourth, we came in sight of Fort Pierre. Finally, after our midday meal was over, we reached the fort, W. Picotte's principal trading post for the Teton Sioux. A dozen braves, painted and decorated, guarded the wares that were unloaded from the boat. Most Sioux women wear still their traditional waist cloth. I sketched the fort and the settlement from the deck of the *St. Ange*. Many people and a large part of the cargo were left here.

They remained at Fort Pierre until the following morning, when—

the Teton warriors gave us a parting salute. Winter huts in several abandoned Indian villages demolished for the purpose of using poles and beams for fire wood.

Two days later they saw the first buffalo, "several buffalo bulls standing on a sand bank," and July 8 "reached Fort Clark, the Ricaras's village." Later in the day Kurz went ashore when, so he wrote:

Several Mandans accompanied us to their near-by settlement. Fourteen huts, mostly then empty, poor remnant of a tribe. A storm drove us so violently shoreward that we were compelled to halt near those huts. Several Mandans and Minnitarie remained on board and journeyed with us to Fort Berthold, which they regarded as a great favor. The village now inhabited by the Ricaras, or Riks, belonged formerly to the Mandans.

A week after the *St. Ange* had passed Sarpy's trade house, Kurz entered in his journal:

We travel slowly. As Louis has died I am now installed as Mr. Picotte's clerk.

Thus he became associated with the company and continued to hold some position for several months. And so it was that on the morning of July 9 he was told by Picotte to be prepared to remain at Fort Berthold as he had just heard that Kipp, the bourgeois at that post, wished to spend the summer in Canada and, therefore, a clerk must be left in charge.

At midday we saw from afar the white palisades of an Indian village gleaming in the sunlight.

Late in the day the *St. Ange* stopped at Fort Berthold, then continued up the Missouri.

FORT BERTHOLD

The day after his arrival at Fort Berthold, Kurz made this interesting entry in his journal:

What I saw and heard to-day offers me a rich harvest of sketches. The neighborhood in which I now spend my days is a near-by Indian village of 80 clay huts surrounded by palisades and frequented by billiard players, idle lookers-on, horse traders, and Indian squaws engaged in daily tasks. This fort, they say, is always alive with Indians except in winter, when they hunt the buffalo in the surrounding regions. That is another sight I shall enjoy. There is rather little traveling to and from this post. The Monnitarri, or Gros Ventres, as they are called, never go far from their stockades for fear of the Sioux. They are too few to have the protection of different bands of their own tribe. The squaws here plant fields of Indian corn, and after the harvest Crow Indians, a related tribe, come to the village. Now that a treaty of peace is concluded, Assiniboins also come to trade for corn, or rather to beg. The Monnitarri are so reduced by wars and pestilence that Mr. Kipp, in return for 100 buffalo hides, inclosed their habitations with palisades so that they might be secure at least against surprise attacks and consequent extermination. No huts are visible until one has passed through the entrance to their barricade.

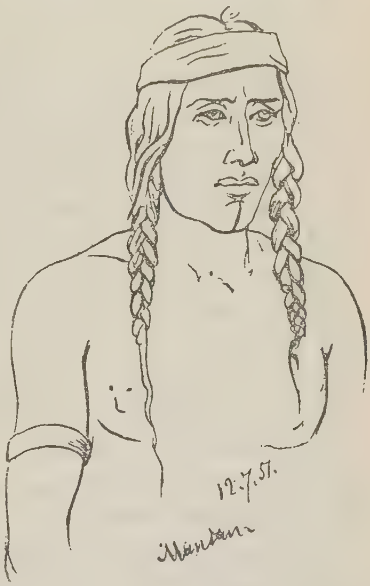


FIG. 2.—Mandan. At Fort Berthold, July 12, 1851

On the morning of July 12, buffalo were sighted on the prairie across the river from the fort. Hunters were soon ferried over in boats made "of raw buffalo hides." They soon returned with a large quantity of meat. Kurz was ever adding to his collection of Indian material, and that day:

In exchange for a blue blanket and a knife I got from a Mandan a buffalo robe elaborately trimmed with vertical stripes of porcupine-quill work.

Sunday, July 13, 1851—an exciting day at Fort Berthold. The village was—

like a swarming beehive. Warriors and young men in arms were hurrying across the plain, others were mounting their horses, a crowd of women were returning in haste from the fields. An Indian called *Le Boeuf court queue* had been shot, they said, by one of the Sioux. He had been at the fort about breakfast time and I had wished to trade with him for an old-style tomahawk—oval stone attached to a very tough dried tail of a buffalo bull.

The body was recovered and carried back to the fort, some coming on horseback, many walking, and others driving dogs drawing loaded *travays*.

Having arrived at the burial ground the dead warrior was taken from his horse and laid on his blanket, his head and chest raised. Relatives sat around him wailing and howling, jerking out their hair, pounding their heads with their fists, tearing their flesh with knife and arrow points until their blood flowed as sacrifice. Friends brought blankets, garments, bright colors as funeral offerings. Meanwhile a scaffold was constructed of four stakes held together with crossbeams. Upon this structure the fallen Mandan, attired after the manner of Indian warriors and wrapped in his robe, was laid beneath the covering of a new blanket. His medicine pouch was fastened to one of the posts. The crowd dispersed; only his widow and his mother remained to wail.

Thus Kurz had witnessed one of the tragedies of the wilderness.

The Indians were becoming very superstitious and believed that Kurz, by making pictures, showing their likenesses on paper, was causing the great sickness that was fatal to many. An epidemic had occurred just after Catlin's visit, again cholera prevailed in the upper Missouri Valley soon after Bodmer and Maximilian had traversed the same region, and now another was in their midst, with the dreaded cholera claiming their friends and relatives. Even while at Belle Vue, Kurz had been warned by Picotte; nevertheless he continued to sketch. On the evening of July 15, after the evening meal, there was great excitement in the fort.

Two young braves were returning with their first scalps! What exultation among the spectators! Every one was eager to extend the first welcome.

The faces of the two—

were painted black with the exception of the tips of their noses—sign of their having performed a *coup*.

They had crossed the river from the other shore, and as soon as they landed presented their weapons—

to those standing nearest them on shore, in token of the first congratulations. One of the persons so honored fastened the two scalps to a long pole and strode into line just behind the victorious braves, singing their song of triumph. Proudly they moved forward, betraying no sign of emotion.

Later the two scalps—

were placed beside the dead *Le Boeuf court queue* as an expiatory offering.

On the following day Kurz finishes a Mandan dictionary of some 600 words. It was compiled according to Kipp's pronunciation for Colonel Mitchell. That same day the *St. Ange* arrived on its return trip from Fort Union. Women were soon engaged in taking packs of 10 buffalo robes to the boat. Kurz noted that—

Indian women in this region carry bundles on their backs by means of broad leather bands that cross upon the breast. Iowa squaws carry their packs

by means of bands across the brow. The difference may be due, however, to the greater weight of the burden here; 10 robes weigh at least 100 pounds.

During the day a dance was held around the two scalps. Thus the young artist was seeing much of interest, although unable to draw and sketch as freely as he desired.

July 18:

To the accompaniment of a tambourine, played by an old man, young Indian women and girls gave a dance in full dress in our courtyard. They formed an ellipse, facing one another, and with feet close together they skipped forward and backward to the rhythmic call of *eh, eh.* Their cheeks were painted red. A few wore feathers in their hair. One carried a cavalryman's saber in her right hand. The dress of Herantza squaws consists of their traditional shirt of deerskin or of blue and white striped ticking or some other cloth made according to their ancient style. The Crows follow the same mode. Their home dresses are usually very greasy and dirty. Their full dress shirts or smocks are trimmed with rows of elk teeth. For the pleasure of witnessing the dance I am indebted to Old Totano.

FIG. 3.—Crow woman wearing garment decorated with elk teeth. At Fort Berthold, July 18, 1851

And another interesting event occurred that day when "The 67 Assiniboin warriors who were put across the river on Thursday the 17" began their homeward journey. The Hidatsa were "mistrustful of my sketching; they say it brings the pestilence." His troubles were increasing, especially as Kipp and his family, P. Gareau, and many others were ill at the fort.

On July 22:

Bellange gave me further instructions in the Indian sign language.

July 26:

The two days just passed were of absorbing interest; a dozen *metisse de la riviere Rouge* (half-breeds from Red River) arrived with a Catholic missionary. They had come from their large camp a day's journey from here. They wanted horses either in exchange or by purchase. All were dressed in bright colors, partly European and partly Indian in style. Tobacco pouches, girdles, knife cases, saddles, shoes, and whips were elaborately decorated with glass beads, porcupine quills, etc., in an artistic work done by the squaws. The young priest, Charles Lacomb, began at once to preach. The priest was sent here by the Bishop of Chicago for the purpose of founding a mission. This is a Catholic territory under the jurisdiction of the Bishop of Chicago. * * * Early this morning we received news that a band of Sauteurs, or Ojibwa, would come from their settlement and make us a visit. Finally, after all members of

the group had their festive array in order, according to Indian custom that is of the greatest importance, they emerged from a grove and marched forward toward us. There were, perhaps, a hundred of them, some in trappings of war, some on foot, while others on horseback flanked the column. Five chiefs, carrying ornamental peace pipes and displaying prominently their trophies in recognition of *coups*, formed the vanguard. Behind them were the warriors singing, beating their drums, and firing their guns. Then came three women. Last in the procession came young men who had not yet won distinction for themselves. Behind the fort, Quatre Ours, the Herantsa chief, and La Longue Cheveleur, the celebrated speaker, awaited their coming. When they came up the Sauteurs paused long enough to hear their speaker's address of welcome, then singing together they withdrew with swift, proud step to the village and sat down in an open space. * * * The five chiefs laid their pipes on the ground in front of them in such a way that the pipe bowl pointed to the hut occupied by Quatre Ours, the stem, to a wooden fork stuck upright in the earth near by. The pipes were not lighted. Now articles of clothing, magnificently ornamented, were brought to the chiefs and placed on the ground in front of their pipe bowls. There were no presentation speeches, but great dignity prevailed. * * * This evening the Sauteurs are off to pitch their camp farther on and to hunt buffalo.

FIG. 4.—Hidatsa. Long Hair, "the celebrated speaker." At Fort Berthold, July 26, 1851

What an interesting and motley gathering, and what subjects for an artist to sketch. That same evening:

One of the *metisse* brought a white buffalo robe to sell and received two good horses for it. Such a skin is very valuable for white or dappled buffalo are extremely rare.

Buffalo were discovered the next day:

Our Indians are over the river again. As soon as they catch sight of the animals in the distance the "soldiers" assemble in their hut—their assembly lodge—to consider whether they will go on the hunt. Their decision is reported by a crier from the lodge. Nobody is allowed to take his own course contrary to the decision of the "soldiers" on the buffalo hunt, because according to the rules all are to enjoy equal opportunities.

On the evening of July 29:

The steamer *Robert Campbell* arrived, bringing supplies for the other company—Primeau, Harney, and Joe Picotte. It left St. Louis on the 2d of July and met the *St. Ange* at Fort Pierre. The fort of the other company is situated on the other side—eastern side—of the village.

Kurz was evidently interested in the songs and games of the many children of the native village. That day he wrote in his journal:

While I was taking a walk on the prairie to-day I met a number of interesting children, playing in groups near their grazing horses. Several little girls, who had made a shelter from the blazing sun with their blankets, were singing to the rhythm of drumbeats. Their song practice soon enticed one of the boys, who were also guarding horses, and he taught a little dwarf to dance. I saw small boys quite frequently at their first shooting practice, with stalks of grass for arrows they aimed at the leaping frogs, and when they hit the mark laughed with delight to see the little white-bellied creatures turn somersaults in their swift movements to escape.

Kurz wrote on August 1:

In this village men set more value on personal adornment and good appearance than do the girls; they take especially good care of their hair and even wear false hair glued to their own, but that is done only by those men who are accredited with *coups*. The hair of the Herantsa Indians is not smeared with grease and has, therefore, a rough, reddish-brown appearance. The men wear their hair either hanging loose or coiled into a knot above the brow. La Longue Cheveleur, as his name implies, is distinguished by his very long hair. I saw him only once when he allowed it to hang down and that was when he delivered the address of welcome to the Sauteurs.

Conditions became worse at Fort Berthold; sickness continued. August 14:

La Grande Cheveleur paid me a visit to-day, bringing one of his friends with him. He entreated me, with signs, to open my sketchbook for them that they might see with their own eyes and decide whether my sketches were really the cause of the sickness so prevalent among them. Owing to the absence of Quartre Ours, who is with Mr. Culbertson and the Assiniboin chiefs at Fort Laramie, Le Grande Cheveleur is now chief of the Herantsas. He is distinguished for his intelligence as well as for his gift of eloquence; Quatre Ours is accredited with more *coups*, having 14 to his account. Grande Cheveleur finds in my drawings nothing in the least to warrant suspicion. He will talk with his people.

Three days later and deaths were more frequent:

The Indians have such dread of the disease that they have determined to hurry away to the hills; they would like to take their families with them and live in the huts they built for summer on the banks of Knife River.

The next day the chief, Le Corbeau Rouge, accused Kurz of being the direct cause of the great sickness, that—

my looking at everything and writing down what I saw was the cause.

Kipp advised him not to allow the Indians to see the sketches as they were becoming more and more excited. Sickness and death throughout the region. August 23:

Aged Indians and the sick are encamped in front of our fort in tiny huts constructed of boughs and twigs. They make use of these shelters, at the same time, for taking their vapor baths. They produce steam by heating stone red-

hot in a fire, prepared in front of the huts then, having tightly closed the one they wish to use, carry the stones inside and pour water upon them.

Many of the older Indians died at that time, and—

If an old woman dies there is nobody to bury her except ourselves. We have already sent two down the river in perforated skin boats—left there to go to the bottom.

Kurz was expecting to leave Fort Berthold and evidently desired to make as many sketches as possible under the conditions. August 26:

Have made a sketch of the great Place of Sacrifice dedicated to the sun and moon. A painted buffalo skull set on the summit of a small mound is surrounded by other skulls, both human and buffalo. In front of every skull a bit of white down is placed on a small stave. Beside the circle of skulls stand two posts to which are hung bear skins. Fastened to the posts are bundles of fagots, above one of the bundles is a fur cap to indicate the man. * * * Also visited the village, now deserted. Entrances to the huts were barricaded. Saw the cask that is said to represent the Ark. Among the clay huts stood a small blockhouse. The casklike structure was not found in the principal village but in a smaller one, probably in the land of the Mandans.

Fig. 5.—Hidatsa. Chief Le Corbeau Rouge. At Fort Berthold, August 7, 1851

It was no longer safe for Kurz to remain at Fort Berthold; the Indians were becoming more enraged and suspicious of his actions. Therefore he decided to go to Fort Union, at the mouth of the Yellowstone.

FORT UNION, NEAR THE MOUTH OF THE YELLOWSTONE

On Monday, September 1, 1851, Kurz, with one companion, an engagee named Bellange, left Fort Berthold for Fort Union. They had poor horses and carried very little in addition to guns and ammunition.

The distance, as the crow flies, is about 170 miles; by the river route more than twice as far.

The grass was high on the prairie and they had great fear of lurking Indians. They passed large herds of buffalo, and on the day before reaching their destination met some Hidatsa Indians by whom they were kindly received and given "choice bits of fresh meat, a great quantity of which was hanging out to be dried by the sun." Late that day they arrived at Fort Williams, "trading post of the opposition, and 3 miles above the mouth of the Yellowstone lay Fort Union." They were soon within the palisade of Fort Union and Kurz met his "new *bourgeois* Denig." Before breakfast on the

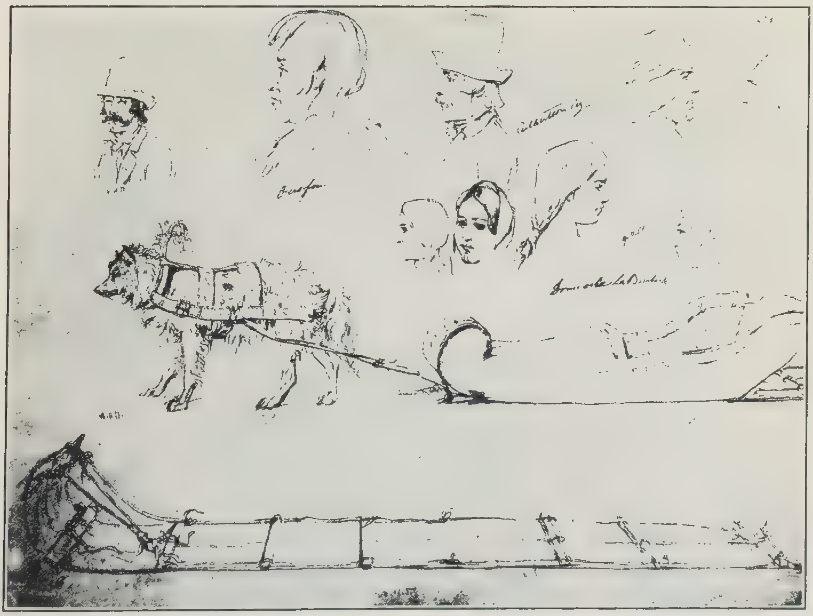
1.—MANDAN. ON RIGHT, KIPP, BOURGEOIS AT FORT BERTHOLD. JULY 14, 1851

2.—CREE. JULY 23, 1851

1.—HIDATSA. JULY 13, 1851

2.—HIDATSA. AUGUST 8, 1851

1.—CROW. PROBABLY CHIEF ROTTENTAIL. OCTOBER 26, 1851



2.—OURS FOU, OR MAD BEAR, CULBERTSON, AND OTHERS AT FORT UNION

1.—WATER-COLOR SIGNED AND DATED "FRED. KURZ, JUNE 24, 1854." COLLECTION OF D. I. BUSHNELL, JR.

Size, 12¾ X 15 inches

2.—SKETCHES MADE AT FORT BERTHOLD, JULY 17, 1851

morning of September 6, Bellange had started on his return journey to Fort Berthold.

Kurz was greatly pleased with his new surroundings and wrote:

I am indebted to Herantza superstition for my removal from a most unpleasant situation, and for a highly interesting journey to this place.

There was much for him to do, and although Denig had him paint and decorate some parts of the Fort he found time to sketch.

My plan is not to write a book on the history, religion, and customs of the Indian race, but rather to depict the romantic life of the Indians, either in oil paintings or in prints.

But his wish was not fulfilled. He was destined to remain at Fort Union through the long winter until the following April, and during that time was told much concerning the manners and ways of life of the Indians by Denig, who had already prepared a manuscript on those interesting subjects.

Comparing conditions at the two posts, Kurz mentioned that:

Fort Berthold, which is really under control of Fort Pierre, is not a trading post of much consequence; trade is carried on with only one tribe and, moreover, business is done for the most part on credit, which frequently results in loss. Here, on the other hand, Assiniboins, Crows, Crees, and half-breeds do their trading. Also Fort Union is the depot or storage house for the more distant posts—Fort Benton and Fort Alexander.

But the palisades could not have been in very good order. Kurz entered in his journal on September 15:

Morgan has gone again to the "Chantier," a place in the forest up the river where they are getting beams for the palisades. The palisades of this Fort are not driven into the ground, as in Fort Berthold, but are fitted into heavy beams that rest upon a foundation of limestone. At this place palisades are further secured by supports of crossed beams on the inside, so that they can not be blown down by the wind. Although it happened once during my stay that on the western side, where the supports were badly decayed, a violent wind did force them down.

While at the Omaha village near Belle Vue, during the month of May, Kurz had witnessed young men and boys playing a certain game. He again mentioned it on September 26 in connection with a description of a similar game played by the Hidatsa. He wrote:

At the Omaha village I saw Indian youths hurling lightweight spears, full tilt, through revolving rings. A very difficult feat but one that affords superb exercise for the body, because throughout the game the players run continually up and down the course and at the same time bring their muscles into further action by hurling a lance at a mark that is in constant motion.

He continued:

Herantza are fond of the so-called billiard game which, weather permitting, they practice constantly in and about their village. They play the game with

a wand that they throw with full strength toward a hoop rolling along the ground. This wand has four markings indicated with leather, and at the end a pad made of leather strips, scraps of cloth, or even bunches of grass. The winner starts the hoop, both players run along beside it and throw their wands, the flight of which is retarded by the pads—called "idi" by the Herantza—so that they do not take too wide a range over the smooth course. To be sure, the ground is not as smooth as a floor; it is uneven but cleared of pebbles and trash. According to that mark on the wand on which the hoop, in falling, rests, they reckon the game. Although they put up, always, some small object at the beginning of the game, the stakes are steadily increased until they mount quite high. Some members of the Herantza Tribe devote themselves exclusively to this game and never take part in the hunt.

Players of the game, some holding their wands, were sketched by Kurz. The drawing, a page in his sketchbook, is now reproduced as Plate 6, Figure 2.

Kurz witnessed many interesting gatherings during his stay at Fort Union, and, fortunately, made many notes in his journal. On September 27 he wrote of certain happenings:

This afternoon about 50 Cree Indians, men, women, and boys, came from a near-by village to pay us a visit. La Rossade de Cou, La Velle Jamb, and Le Conteau led them. These are the first Crees I have seen. They came to beg rather than to barter. Their real purpose is to try and find out at which fort they can get the best price for their skins and furs. They have to be attracted with gifts and much liberality, else they trade with the Hudson's Bay Company.

And the next day:

Nearly all of the Crees have left. They wear their ancient and original dress almost entirely—garments made of dressed skins, and buffalo robes. * * * Crees are said to be most valiant warriors, excellent marksmen with the rifle, but very cautious in trade.

A Cree squaw was seen—

with the upper part of her body entirely uncovered; a sign of mourning for the loss of a child.

And:

Indians believe in spirits; although they have never had any visible evidence they talk with them and take counsel. They think that spirits follow them—not on the ground but about 2 feet above.

October 13:

While we were weighing the meat and hanging it up, so as to prevent mold and also to keep it out of the way of hordes of mice (there are no rats in this fort nor at Fort Berthold), there arrived a great band of Assiniboins, including many squaws, with laden horses and dogs.

Kurz had previously mentioned that Denig had purchased some 15,000 pounds of dried meat at an Assiniboin village and had transported it to Fort Union for use during the winter.

About this time a party of Hidatsa arrived at Fort Union, and on the night of the 17th they and some Assiniboins who resided near the fort had a game. It was witnessed by Kurz, and the scene was thus described:

The room, dimly lighted by the open fire and one candle, was crowded with performers and onlookers. According to Indian custom, eight Herantsa and seven Assiniboins sat opposite one another on the floor, encircled about a pile of bows, quivers, knives, calico, etc., and were playing a game. Two Assiniboins were making motions in every direction with their fists, or rather with their closed hands, swiftly passing, in the meantime, a bullet from one hand to the other, while the other members of their party sang "e, e, e, eh, e, e, e, ah," keeping time by beating a tattoo with sticks on wash basins and boiler tops. In an excited state of eager expectation both singers and players swayed their bodies continually from the hips. One of the Hidatsa, who had laid the stake in opposition to the two Assiniboins, had to guess where, or rather in which of the players' fists, the bullet was to be found. When he felt sure that he knew, he made a quick thrust with his left arm in the direction of the fist in which he supposed the ball to be, struck violently on his breast with his right hand, and with a cry designated the fist mentioned. If he failed to guess the right one, the winners whooped for joy and gathered in their stakes. Then they smoked from the same pipe as a mark of continued friendship, and other contestants began the same game again.

The game closed "after an Assiniboin had won almost every stake the Herantsa had put up."

A large party of Crees, including women and children and led by Le Tout Pique, reached Fort Union on the morning of the 19th. Later in the day they performed an interesting ceremony to bind their friendship. On the 26th a band of Crows arrived with their great chief, Rottentail. And:

As soon as the Crow squaws had brought in their heavy bundles and everything was in order, Rottentail produced a superb military headdress which he put on the *bourgeois'* head, and then hung a handsome buffalo robe on his shoulders. Denig looked comical, but no one dared laugh.

The pipe was smoked and the talks began. Three Assiniboin were killed, evidently by some Blackfeet, and on the 29th Kurz mentioned in his journal that:

Relatives of the three Assiniboin who were slain have planted a pole and fastened thereon two leather pouches that belonged to the dead. There for a long time they wailed and made blood offerings by cutting their arms, cheeks, heads, and legs until blood flowed. One of the dead men is that Assiniboin who won the high stakes from the Herantsa; he was a son of the Assiniboin chief, L'Ours Fou, or Mad Bear.

Thus during the autumn of 1851 many Indians, belonging to several tribes, visited Fort Union. They came to trade, to obtain necessary supplies for immediate use, and to plan for future intercourse

with the post. By November 20 the river was blocked with ice; it soon closed, and a few days later Kurz wrote:

> Apsahrokes (Crows) and Assiniboins are encamped across the river only a few miles from here, and now that the stream is frozen over they are continually visiting the fort. They transact no business, but do much eating and smoking. I have become acquainted with another Crow chief; his name is Four Rivers. He is a very powerful man, both in regard to physique and in relationships.

And referring to the Crow dress:

> The men make a great show of their apparel and decorations. In their hair they hang hollow tubes of white and violet-colored porcelain and about their necks they hang long ropes of the same ornaments. They decorate their leather pouches with beads, and likewise those broad bands by means of which they swing their bows, quivers, and rifles across their shoulders. Only the men are allowed to make themselves conspicuous with long hair, and to that end—as do their relatives the Herantsa—they stick on false hair as a means of making their own seem longer than it really is. Squaws among the Crow tribe cut their hair short above the eyes and on the neck.

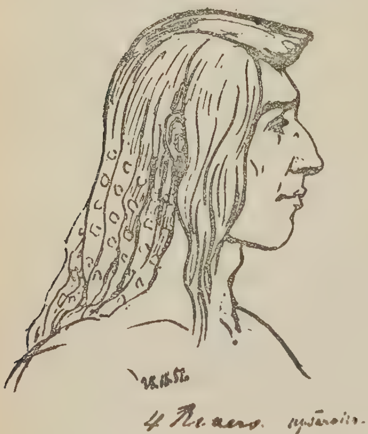


Fig. 6.—Crow. Chief Four Rivers. At Fort Union, November 25, 1851

Kurz had become interested in the care and preparation of buffalo robes. He had probably often watched the women when they were busily engaged in tanning the skins. His rather brief description of the process is of much interest.

> One squaw dresses a buffalo hide in three or four days just as well, and makes the skin just as soft and durable, as it takes our leather dressers six months to do. First they stretch the raw hide on the ground and fasten it down with pegs or wooden pins, and with some sharp instrument, or a piece of bone, scrape off every particle of flesh, which is eagerly devoured by the hungry dogs. If the skin is not to be dressed until later, they leave it spread in the air to dry, until it becomes quite hard. If, however, they intend to prepare the robe at once, they rub the hide for one entire day with liver, fat, or the brain of a deer, soften the skin, leave it for two or three days—according to the season or temperature—until the grease soaks in; then they dry it at a slow fire, constantly beating or rubbing it with a stone until it becomes uniformly soft and pliable. This rubbing is of the greatest importance in the dressing of skins after the Indian fashion. As soon as the hide has been prepared as already described and is quite dry, they begin the fatiguing process of rubbing it around a taut rope of horsehair or of braided leather to make it smooth; then it often receives a final rubbing with pumice stone. Such work is most difficult, for even the scraping of the hides has to be done in a stooped position that is very fatiguing. As the brain of a deer is finer and more rare than liver or tallow it is used primarily in the preparation of deerskins. Hides of

deer are placed in the final stage of their preparation over a slow fire covered with green sprays of sumac and smoked. Owing to this process they suffer less injury from water. They become golden brown in color and retain for quite a while the odor of smoke, which repels mosquitoes and moths.

With the coming and going of many Indians, Kurz discovered much to interest and amuse him, and the weeks and months passed. On January 11, 1852, he—

saw four Assiniboin squaws playing a new game. They sat in a row before the fire. They had four disks, about 6 inches long, attached to the ends of wands sharpened to a point. On two of the wands there were disks having the figure of a man on the upper surface; on the other two the upper surface of the disks bore the figure of a hand. The under surfaces were not marked at all. One after another the squaws would seize the four wands at the upper ends and throw them on the floor with the points turned downward, so as to make them fall over with all the decorated surfaces of the disks turned upward. Whoever succeeded in doing that won double the stakes. If all unmarked surfaces turned up, that counted simply a score; if both marked with the figure of a man or both marked with a hand were turned, that counted half as much. The stakes consisted of grains of corn, a certain number designated, according to agreement, stipulated objects such as ornaments, clothing, etc.

The game was played by both men and women.

On January 12, 1852:

La Gras brought bad news from the Yellowstone. The river is out of its banks; has overflowed and inundated Rottentail's camp. His largest tent, made of 25 buffalo skins put together, his stock of raw buffalo hides, together with those already tanned, his clothing, decorations, everything was carried off by the waters.

Late that month it became necessary to secure a greater quantity of meat for the ever-increasing number of individuals at the fort, as many had come together at the post. A camp was therefore established about 12 miles distant on the banks of the Yellowstone, but later removed nearer the Missouri. Kurz spent some days at the camp, away from the fort, and evidently enjoyed sketching and drawing without restraint.

Kurz wrote in his journal on January 29:

To-day the expressman went on his way, with one companion and a pack horse, to St. Louis. A difficult undertaking at this time of year—2,500 miles on foot to St. Joe, from which point he may travel by steamer.

He wrote on February 22:

For a week there has been nothing new to record. Time passes quickly. My studies increase in number, because I make a sketch of every little thing that I shall use later on in paintings representative of life in this region. Two Cree Indians brought more than 100 robes for which they received a better price than is usually paid. This was due to the fact that they were heretofore customers of the Opposition.

That Kurz was ever looking for interesting objects to add to his collection has been shown by many notes in his journal. While riding near the fort on March 27 he found a most interesting piece—

a medicine doll lying on the trail. Such images are said to have the power to invoke spirits and also to exert curative effects on sick children. It is a stuffed doll, made of tanned skin of an animal. It is about 2 feet high and adorned with the usual ornaments children wear—bracelets and a necklace of "dove's eggs" made of blue and white porcelain. An Indian squaw doctor who attends to sick children lost this conjuring doll; therefore I dare not let the squaws at our camp know that it is in my possession.

April 1:

Since last Saturday winter has returned with rigor. A heavy fall of snow, frightful cold, and violent north wind.

Kurz was at the camp some miles from Fort Union, cold, weakened, and discouraged. He wished for a change and did not realize how quickly his wish would be a reality.

LEAVES FORT UNION

On April 17, Culbertson arrived at Fort Union from higher up the Missouri, from the country of the Blackfeet. Kurz arranged to accompany him on his journey down the river, and on April 19 wrote in his journal:

Left Fort Union at 11 o'clock this morning to begin my return journey home. My studies in this country are now completed.

They had a keel boat with a cabin—

which will protect us from wind and frost. The cabin has a flat roof, on top of which the pilot manipulates the lengthened rudder.

He had difficulty in learning to row properly. He gave the names of the party of 12:

Baptiste Champagne was at the helm, Morgan and I, together with Hawthorn, Cadotte, Joe Delores, and three Canadians, assisted now and then by a young Blackfoot (Culbertson's brother-in-law), took turns at the oars. Our cook was a negro, and Culbertson was in command.

Game was plentiful along the Missouri. On April 23:

Cadotte killed a big horn that had left the herd and was clambering down a steep bluff.

A buffalo was killed the following day, and they reached Fort Berthold at sunset of April 25.

In the neighborhood of the fort I saw a great many tents occupied by Assiniboins and Apsahrokes.

Kurz left Fort Berthold at sunrise on April 26.

We came rapidly down the river. Stopped at Fort Clark. While the *bourgeois* went to talk with Dorson, I watched a ball game played by Ricara girls. Many prairie fires. We spent the night at the mouth of the Cannon Ball River.

On May 1 the party reached the mouth of the Little Cheyenne and there found "great blocks of ice caught in the boughs of trees along the shore." Two days later they arrived at Fort Pierre, and all during the day had "seen groups of antelopes along the banks of the river." May 4:

Have had to remain at the fort on account of a violent storm. Our cabin was broken to pieces, so that we had to put up a tent in its place.

They left Fort Pierre on May 5, and that day "found the abandoned forts, Lookout and Nedeune, already in ruins." Two days later:

We overtook Decoteaux, Sarpy's clerk from L'Eau Qui Court, in his long skin boat, and got some fish from him. While eating supper we passed L'Eau Qui Court.

Thus they continued to float and row down the rushing waters of the Missouri, passing many places already known. During the morning of May 11 they reached Belle Vue where, later in the day, they went aboard the *St. Paul*, which landed them safely in St. Louis on the 25th of May.

Kurz remained in St. Louis some weeks, not having any very definite plans for the future. But he decided to return to Bern, and consequently left St. Louis on August 11, when, so he wrote in his journal:

The stagecoach stopped at the hotel for me. We crossed the river and proceeded rapidly across the plains of Illinois. With heavy heart I took leave of the Mississippi and of Cahokia.

After an absence of about six years he returned to his home in Bern, Switzerland, September 24, 1852.

Kurz returned home ill and weakened, and some months passed before he regained health and strength. Then he devoted much time to his chosen work and produced a number of finished pictures, in water color and oil, from his sketches taken back from America. One of his water colors made after his return to Bern is reproduced in Plate 8. This bears the legend: "Scene am Landungplatze des Monitarri Dorfes am Missouri," and is signed and dated June 24, 1854. A sketch made at Fort Berthold, dated July 17, 1851, is reproduced in the same plate for comparison with the water color. The village of the Hidatsa, or Monitarri, stood just beyond Fort Berthold.

The sketches made by the young Swiss artist many years ago are clear and graphic. His journal contains many notes of great ethnological and historical interest. Thus drawings and journal together reveal the appearance and the manners and customs of the Indians and trappers, traders, and engagees, who frequented the posts in the upper Missouri Valley about the middle of the last century—a portrayal of a phase of life in the American wilderness that belongs to the past, never to return.

NOTE ON THE PRINCIPLES AND PROCESS OF X-RAY EXAMINATION OF PAINTINGS

By Alan Burroughs

Research worker in X ray at the Fogg Museum of Art, Cambridge, Mass.

[With 9 plates]

Without special training in science, the experimenter in the X raying of pictures can receive encouragement from an interest in art and connoisseurship sufficient to attempt a more or less scientific study of paintings. He feels that a reliable method of analysis is needed to supplement the emotional process which is usual in criticism. It might be considered presumptuous were there not expert physicists who have prepared the way. Dr. André Cheron in Paris, Doctor Faber in Germany, and others were the pioneers. Even without their specific experiments, the application of X rays to the study of pictures must, it seems, have followed naturally from the broadening of the X-ray processes so as to include a variety of industrial and social uses.

In the present case, however, the possibility of a new use for the rays came by chance from the suggestion of Russell A. Plimpton, director of the Minneapolis Institute of Arts, who wished to know the contents of a mummy case in the Institute's collection. The X ray showed a broken skeleton and an extra skull reposing between the thigh bones of the body. That presented another and quite different problem. What struck the imagination of the curator of paintings was the fact that the painted ornament on the outside of the case was recorded faintly on the X-ray film. With permission from Mr. Plimpton, the author then X rayed a few paintings, finding much to puzzle him and some details worth study. It was not long before an opportunity was found to present an outline of experiments for development to the Cleveland Museum of Art. Director Whiting thereupon forwarded the outline to the Fogg Museum of Art at

Cambridge, where are greater facilities for work of this nature. The first experiments at the Fogg Museum, occupying a three months' leave of absence from the Minneapolis Institute, proved that the X ray does no injury to works of art. And the last 18 months have been devoted, directly under the auspices of the Fogg Museum, to the forming of a collection of X-ray films varied in its scope. This has been possible through the further cooperation of the Cleveland Museum and the interest of museum officials in New York, Paris, Berlin, Chicago, Boston, Philadelphia, London, Brussels, Antwerp, Bruges, and Ghent.

As a result of cooperative effort and a year and a half of research, much information has been gained about artists and paintings, but little about X-ray principles. The principle utilized is similar to that used for diagnostical work in hospitals. Anyone who has been X rayed for a broken bone knows something about it. The bulb, placed on one side of the object to be examined, sends out penetrating "waves" which cast shadows of objects in their path upon a sensitive film, placed on the other side of the object. In the body, bone is denser than flesh and throws a darker shadow. In a picture, some pigments are denser than others or more thickly applied. Of course, the total density of the body is greater than that of a painting, whether on wood or canvass. This means that the exposure used in X raying pictures must be considerably less. Furthermore, the lower the voltage, the more delicate, or selective, the ray, supposedly, which is an advantage in bringing out the difference between pigments only slightly varied in density.

During a year and a half it might have been possible to develop a highly specialized "technique" which would fall approximately halfway between that used for ordinary medical work and that used in the most delicate treatment of skin diseases. But the results so far obtained have justified a continuation of the "technique" first developed and now in use. The fact is that a difference of 5,000 volts one way or another in the exposure of the same picture was found to yield no appreciable differences in the films, and that a difference of 10,000 volts more or less than the middle or best exposure is negligible. For each picture there is one exposure which gives the utmost definition. But practical exposures can usually be made with an intensity of between 15,000 and 50,000 volts.

The reason for this wide range may be found through study of the tables of density of the materials which go into the making of a picture. These are presented in the authoritative works by Prof. A. P. Laurie and Sir Arthur H. Church, dealing, respectively, with the pigments of the old masters and the chemistry of paints. Simple experiments assert the same conclusion. When a chart of many

colors, pure and mixed, is X rayed, one notes that only a few are undeniably dense and that others, even under the ideal conditions of the experiment, are alike in weakness or in utter penetrability. The whites are generally heavy, since the common forms of white pigment are made from zinc or lead. Mercury vermilion has a not surprising density. All metal and mineral compounds have an effect in the X ray. But vegetable colors or chemical compounds, used to-day as substitutes for the old earths and minerals, show differences in density only when the X ray is so soft that it will not penetrate the coat of plaster or white pigment which was ordinarily used as a ground or basis for painting. We are faced, then, with the conclusion that our study of pictures with the X ray is based on the density of a comparatively few colors.

Fortunately for our study these paints were indispensable to the old masters. White lead and dense earth colors are worked generally into all parts of old pictures. We see in the X ray the design of the picture, the outlines, and the brush marks recorded in the underpainting as well as the surface painting. If an artist began painting a profile to the left and then painted over it a full view of the face, we may trace both efforts in the X ray. If he shifted an outline a mere eighth of an inch, we may note the fact in the X ray. If the picture had once been pierced with holes and these holes painted over, we may see the holes. And if two men have worked on the same picture in different styles (like different handwritings) we may be able to distinguish between them more carefully in the X ray than on the surface of the work.

In utilizing these facts one moves slowly. The process, as distinct from the principles involved, is rather complicated. In the first place general conditions may indicate the genuineness of a picture, since modern pictures and workmanship differ in the X-ray shadowgraph in characteristic fashion. Then comparison between the X ray and the painted surface tells us which shapes or brush marks recorded on the film, but not visible on the surface of the picture, must be inside the painting, and therefore earlier in date. Finally, close observation of style and condition may suggest facts which can be compared with the evidence obtained from X rays of undoubted, dated, and well-preserved pictures.

It is fairly evident that the larger the collection of X rays the greater one's knowledge and confidence in the value of careful comparison. The Fogg Museum now has a file of about 1,000, representing the characteristics of many artists and illustrating the problems lying in wait for the student. The collection is far from complete. But it is already serviceable, suggesting in detail the complications already mentioned. "Accepted" pictures by the same artist, for example,

may show identical treatment or some distinct differences due to changes in technique or point of view. Generally speaking, an artist's early work lacks the emphasis or sharply characteristic traits of his mature style. Or two distinctly characteristic styles may be found in the mature work of the same career. Rembrandt comes to mind and Velasquez. In the first the greater freedom of his later years shows in the greater liberties he has taken with his brushes, making one complex stroke perform rapidly that which he accomplished before with several more deliberate strokes. Velasquez, on the other hand, seems to have changed his whole method, leaving a rather dense, well-prepared underpainting for a method composed chiefly of very thin glazes. An experimental artist like Rembrandt must always be considered dangerous to pigeonhole, since he may paint one portrait entirely in glazes and then another with heavy coats of pigment, depending on his interest at the moment and his particular purpose.

Another danger in this study with X-ray films is the assumption that techniques which seem similar are necessarily the product of the same artist. The early works of Raphael and of Perugino, whom Raphael influenced, show in the cases of documented examples that the two painted by the same method and that they differed chiefly in their spiritual and less tangible characteristics, revealed by the X ray vaguely and circumstantially. Many early Flemish works are so similar in method that they might seem identical in the X-ray film had not the experimenter grown accustomed to minute differences. One looks for general similarities to establish the origins and background of an artist and for precise differences, consistently found, to establish individualities.

Just what these differences are can best be described by reference to a common ground of experience. They are, like the characteristics of handwriting, developed by habit. It becomes natural for some one to make capital L's with a flowing line and to join some letters with a loop; he may also cross t's with a curving line. Another individual may possibly make the same L's and cross t's the same way. But the chances are he will not loop the same connections or do other things to exactly the same degree as the first. No *one* difference makes us sure the two are different individuals, but a *combination* of differences and perhaps a few resemblances does. In painting, the methods of handling high lights, outlines, backgrounds, areas of flat colors, corrections, folds, depths, or any particular detail often repeated, such as finger nails, nostrils, eyelids, all combine to indicate individuality of workmanship.

Thus confronted by various possibilities and probabilities, the experimenter concludes that the X ray is not necessarily a court of final

appeal in connoisseurship, but has shown a capacity to aid in "diagnostical" work in esthetics. The illustrations may emphasize the point. They include examples of pictures on panel and on canvas, of repainting over a damaged surface, of alterations made by the artist and alterations made by some one else at a later time. The X ray of a forgery is also reproduced to show how definitely chemical colors are penetrated, even when those colors appear genuinely old to the eye and resist the ordinary tests of a restorer's inquiry. These illustrations may do what this brief report can not—bring to a focus the reasons why the art museum of a large university deems these experiments worth a continued effort.

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PHOTOGRAPH OF THE HEAD OF A PORTRAIT ON CANVAS BY BADILE (?)

(Courtesy of the Fogg Art Museum)

[illegible]

[illegible]

[illegible]

X RAY OF THIS HEAD, SHOWING THE DAMAGE TO THE OLD PAINT WHICH THE RESTORER'S BRUSH HAS COVERED

(Courtesy of the Fogg Art Museum)

PHOTOGRAPH OF THE PAINTING "MARS AND VENUS" BY VERONESE

(Courtesy of the Metropolitan Museum of Art)

X RAY OF THE HEAD OF VENUS, SHOWING VERONESE'S FIRST INTENT AT THE RIGHT. HE PAINTED THIS OUT WHEN HE CHANGED THE HEAD TO ITS PRESENT VERTICAL POSITION

(Courtesy of the Metropolitan Museum of Art)

PHOTOGRAPH OF A DETAIL OF THE PAINTING "CHRIST CROWNED," ASCRIBED TO TINTORRETTO IN SPITE OF THE FACT THAT THIS HEAD IS NOT PAINTED IN TINTONRETTO'S MANNER

(Courtesy of the Fogg Art Museum)

X RAY OF THE DETAIL OF THE PAINTING "CHRIST CROWNED," SHOWING FREER AND MORE INTERESTING BRUSHWORK UNDERNEATH THE PRESENT SURFACE

Note that Tintoretto intended this figure to be an old man with a beard, which was covered by the head of a younger man. (Courtesy of Fogg Art Museum)

PHOTOGRAPH OF THE PAINTING "VIRGIN AND CHILD WITH ST. JOHN" BY ANTONELLO DA MESSINA

(Courtesy of the Metropolitan Museum of Art)

X RAY OF THE VIRGIN'S HEAD BY ANTONELLO DA MESSINA

This is typical of the appearance of any old painting on wood panel; the bands running through the X ray are the shadows of the wooden stripes of "cradling" on the back. A close examination of the Virgin's face reveals the fact that the artist began the painting in a slightly different position. Two lines for the center of the mouth, two nostrils on the same side of the nose, and two lines for the bottom of the chin enable one to place the first position to the left and a little higher than the finished version. (Courtesy of the Metropolitan Museum of Art)

X RAY OF A FORGED "CRUCIFIXION," DONE IN THE SIENESE MANNER OF THE XIV CENTURY, SHOWING THE LACK OF DENSITY OF SOME MODERN COLORS. THE NUMERAL IN THE UPPER CORNER IDENTIFIES THE POSITION OF THE PICTURE. NOTE THE NAIL AT THE BOTTOM AND A SUGGESTION OF PIGMENT ABOVE IT

(Courtesy of the Fogg Art Museum)

LENGTHENING OF HUMAN LIFE IN RETROSPECT AND PROSPECT [1]

By Irving Fisher, Fellow, A. P. H. A.

Professor of Economics, Yale University, New Haven, Conn.

At its Cleveland meeting in 1922, the American Public Health Association adopted a long resolution, prompted by the death, at the age of 99, of Dr. Stephen Smith, one of its founders. I quote from this resolution:

> * * * his [Dr. Stephen Smith's] last request and advice to this association a year ago was: * * * "To send messengers of hope in a new scientific standard of long life. * * *" In New Zealand they have all but attained for their people an average length of life of 65 years, and this is 10 years more than we reached in the registration States of the United States in 1920. * * * We, the health workers of our communities, are confident that there is nothing inherently impracticable or extravagant in the proposal we make that many nations may attain such knowledge of the laws of health, appropriate to each age and occupation, to each climate and race, that within the next 50 years as much as 20 years may be added to the expectancy of life which now prevails throughout the United States, and to this goal we dedicate the efforts of our association, as urged by our departed leader, Stephen Smith.

So far as in me lies, I wish to further the objects of this resolution.

First, let me confess that my own studies in health, which may seem a little outside the range of my profession, were first stimulated by my having had tuberculosis 27 years ago. From this personal interest I was gradually led to see the great economic importance of health and to appreciate Emerson's dictum that "the first wealth is health."

In 1908 I was made a member of President Roosevelt's Conservation Commission for the express purpose of adding to its study of the economic conservation of forests, minerals, soils, and waters, that of human life. In my Report on National Vitality, published by the National Conservation Commission in 1909, I utilized all the expert opinion and data then available as to the preventability of various diseases in order to reach a conservative estimate of possible life

[1] Read at the second general session of the American Public Health Association at the fifty-fifth annual meeting at Buffalo, N. Y., Oct. 13, 1926. Reprinted by permission from American Journal of Public Health, January, 1927.

extension. For instance, it was estimated that deaths from tuberculosis could be prevented by 75 per cent, thereby adding 2.5 years to human life; those from diarrhea and enteritis, 60 per cent, adding 2.3 years; erysipelas, 30 per cent, adding 0.9 year; acute nephritis, 45 per cent, adding 0.9 year; typhoid fever, 85 per cent, adding 0.6

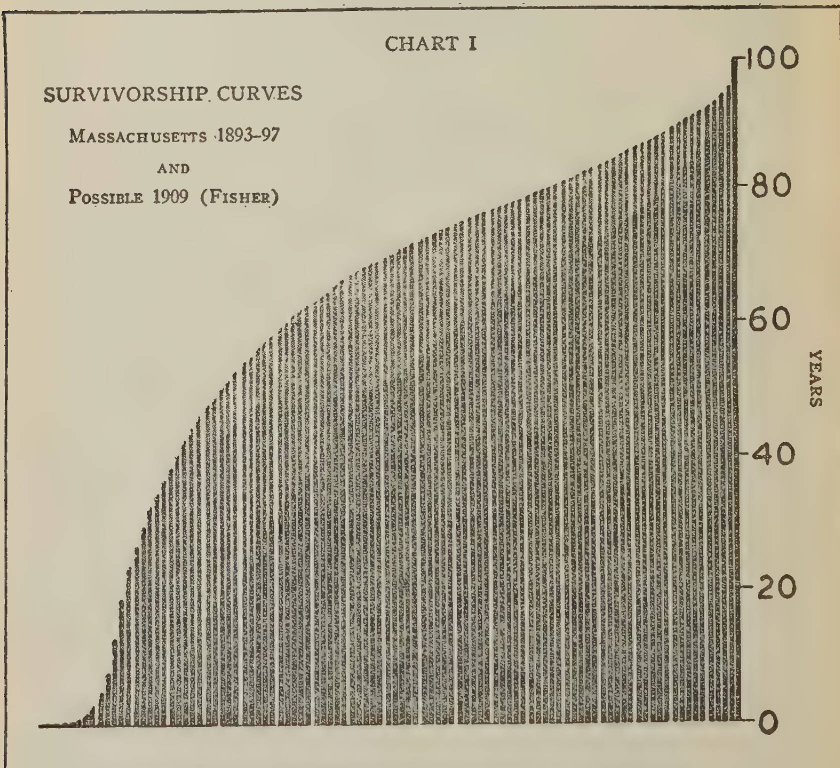

FIG. 1.—Showing distribution of an average group of 100 human beings arranged by the number of years each person lived, and also showing graphically these years. The 100 vertical bars in this chart represent 100 persons in a representative group. The height of the bars shows the number of years of life enjoyed by each person. The black bars portray conditions in Massachusetts in the nineties and the gray portion added to each of these black bars shows how many additional years of life each person was entitled to, according to Professor Fisher's estimate, made in 1909, and what would be the possible improvement which could be expected

Chart II shows that Professor Fisher's estimate had already been nearly reached throughout the United States registration area by 1917.

year; diphtheria, 70 per cent, adding 0.5 year. Cancer was set down with a zero preventability, and diabetes was set down with only a 10 per cent preventability.

The chief net results (1)[2] were that, by preventing diseases of infancy, at least 4.4 years could be added to the average duration of life; by preventing diseases of middle life (diseases having a median

[2] Numbers in parentheses designate references at the end of this article.

death incidence between the ages of 23 and 49) at least 6.8 years could be added, and that the total prolongation of life which would come from applying all the preventabilities was about 15 years. B. H. Forsyth by more refined methods obtained 13 years (26). Figure I shows the survivorship curve (for Massachusetts, 1893–1897), the latest available in 1909, and what was claimed in 1909 as possible.

SOME HOPES REALIZED

These figures took no account of future advances in preventive science. They signified merely what could be attained by applying knowledge existing in 1908. This forecast of 15 years to be added to the human lease of life, though extremely conservative, seemed preposterous to many when published, just as to-day the Stephen Smith resolution setting a goal of 20 years seems to many quite preposterous. It is therefore interesting to note that in the 17 short years since the report on national vitality was published most of the preventabilities then estimated as possible have already been realized, and that almost all of the 15 years calculated as attainable have actually been attained.

Thus Dublin tells us in 1922 that since 1911 tuberculosis has declined 50 per cent among those insured in the Metropolitan Life Insurance Co. and almost as much in the general population of a number of progressive cities; this 50 per cent already attained is two-thirds of the preventability set down for tuberculosis in 1909. That the remaining third is easily attainable is indicated by the tuberculosis demonstration in Framingham, Mass., conducted by the Metropolitan Life Insurance Co. There the death rate fell 69 per cent in only seven years; this is almost the total 75 per cent preventability set down in 1909.

Typhoid fever has declined 87½ per cent as against the 85 per cent set down as possible in 1909. Diphtheria has declined 44 per cent as against the 70 per cent set down, and now we know that diphtheria can be practically wiped out. It was recently announced by the American Museum of Safety that:

> Twenty years of accident prevention in the plants of the United States Steel Corporation had resulted in a reduction of more than 60 per cent in fatal accidents and in a reduction of more than 80 per cent in less serious injuries to workmen.

In my 1909 report only 35 per cent was set down as the preventability of deaths by violence. On the other hand, the coming of the automobile has greatly increased the number of street accidents. Automobile accidents rose from 8 per million of population in 1908, to 149 in 1923. Consequently deaths from violence (now called " ex-

ternal causes") of all sorts in the United States have fallen only 18 per cent.

Turning to diarrhea and enteritis, the census shows a decrease of 66 per cent, while, as Doctor Dublin points out, the death rates in 23 American cities have declined by 79 per cent; both of these are more than the 60 per cent set down. In fact, as Dublin also points out, the whole infant mortality rate has been already cut 60 per cent; only 47 per cent was set down. The death rate of children at ages 1 to 4 years has already declined 50 per cent; 67 per cent was set down (for diseases of children having a median death age from 2 to 8).

The mortality among graduates of women's colleges where medical inspection, supervision, and instruction have been used is less than one-third that of the general population (3), showing that the ordinary mortality of youth is two-thirds preventable. At the University of Wisconsin (4), as the result of medical supervision supplied by the State to students, it was found that:

> The loss of time due to bed illness has been reduced 40 to 60 per cent, due to the early treatment of preventable conditions. The frequent consultations have reduced serious illness and its complications by at least 50 per cent. During the eight years of this medical supervision the university death rate has been reduced to only one-fourth of the general expectant rate, exclusive of tuberculosis.

FUTURE POSSIBILITIES

All these facts show how readily illness and disease will yield to preventive measures and that the forecasts made in 1909 were more than justified.

In 1922 Dublin published an independent forecast in his Possibility of Extending Human Life (5), reviewing the more recent and reliable data, and showing that 10 years can still be added to human life by applying existing knowledge alone, without taking account of future discoveries or improvements in habits of living. Figure II shows the survivorship curve (for United States, 1920) and Dublin's claim of what is possible.

The reason Dublin left out the effects of changes in habits and in the advance of hygienic science was merely because for these two factors he had no positive data and not because he thought hygienic science would henceforth stand still, or human habits either.

There is no way of accurately estimating the effect of these two factors—new discoveries and changing habits. But we have something to go by in the rates at which life has been lengthening in the past. Figure III shows the chief results of studies in past longevity. As I pointed out in 1909 (1), during the seventeenth and eighteenth centuries in Europe human life was lengthening at the rate of about 4 years per century. During the first three-quarters of the nineteenth

century the rate was 9 years per century. During the last quarter it was 14 years per century in Massachusetts, 17 years per century in Europe in general, and 27 years per century in Prussia in particular. More recent data show that in the first quarter of the twentieth century, for the United States, England, and Germany, life lengthened at the amazing pace of 40 years per century. Raymond Pearl finds

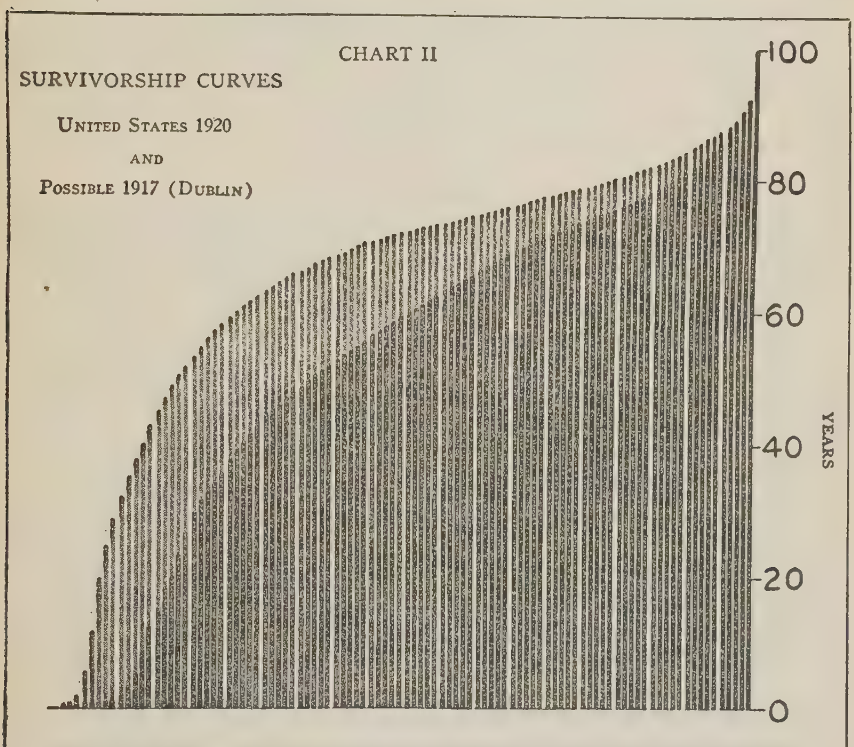

FIG. 2.—The 100 vertical bars in this chart represent 100 persons in a representative group. The height of the bars shows the number of years of life enjoyed by each person. The black vertical bars in this chart portray conditions in the United States, throughout the registration area, in 1920, and the gray tops above the black bars show what additional lifetimes might be expected, as a reasonable human goal, according to the estimates made by Louis I. Dublin, as early as 1917

It will be seen that a marked increase has taken place in the length of the average lifetime in the last quarter century by comparing the black bars in this chart with the black bars in Chart I, showing conditions in Massachusetts in the nineties

that Baltimore during the last half century has been lengthening human life at the rate of 30 years per century, while London shows a rate of 45 years per century. But it is Germany which again reaches high-water mark with a rate of 60 years per century!

But are these rates destined to keep up, or are they, like the speed of 60 miles an hour which an automobile reaches for a brief moment, destined soon to recede? Dr. Hornell Hart, of Bryn Mawr Col-

lege (7), believes that not only will the present rate be kept up, but even that its recent acceleration will be maintained. He concludes that by the year 2000 the average duration of human life will be 100 years and that many babies will then be born destined to live to be 200. In support of this startling prognosis, Doctor Hart says:

The tendency for the past million years has been toward accelerating increases in man's power to control his environment. This is conclusively shown by the study of the cutting tools used by man from the Pliocene age, hundreds of thousands of years ago, up to 1925. In a more definitely measurable way this acceleration is obvious in such variables as the speed with which man has been able to move, the rapidity with which he has been able to make copies of a message, the length of the span over which he could throw an arch or

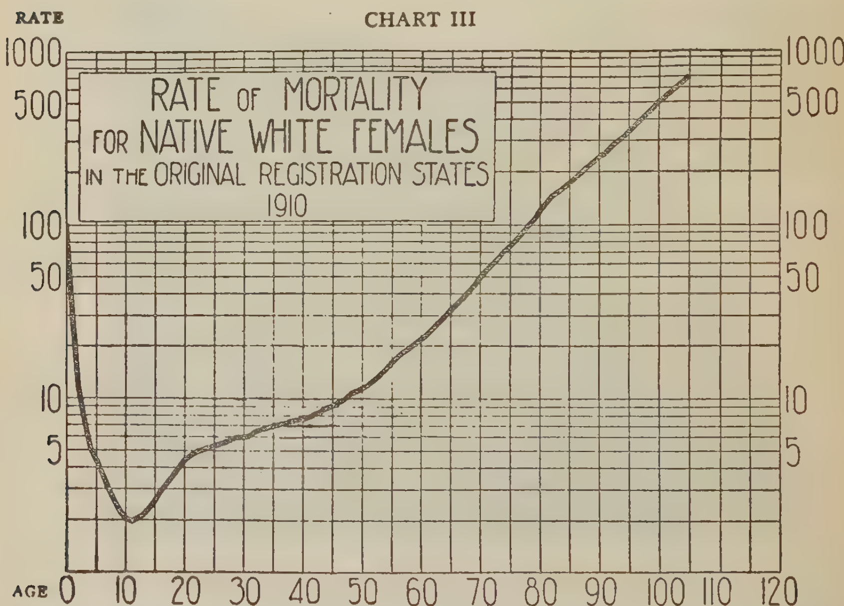

FIG. 3.—The curve ends at 105 years only for lack of sufficient data. It shows no tendency to approach a limit, *i. e.*, a vertical direction

bridge, the speed with which new inventions have been diffused over the world, and the distance at which one man could kill another. Curves drawn to represent any one of these accelerating developments will suggest the same upward sweep which is evident in the line representing gains in expectation of life.

Instead of showing signs of having used up the major possibilities in preventive medicine, research in this field is making major new discoveries which bid fair to eclipse past attainments in life saving. The discoveries relating to internal secretions and to the functions of vitamins are just beginning to be exploited. Antiseptics many times as powerful as any in past use have very recently been discovered. Important progress is being made in relation to cancer and diseases of the heart and blood vessels—two of the most serious causes of death in later life. The potential immortality of the cells of the body has been demonstrated. Not only are such discoveries being announced with increasing frequency, but new research laboratories are constantly being

opened; new apparatus and new technics are being discovered and brought into use; an increasing number of trained investigators is available, and unprecedented funds are being placed at the service of scientists in this field.

But, plausible as this all sounds, if we are seeking to extend the figures of past experience, we hesitate to follow Doctor Hart's method. He virtually assumes that the curve representing the average duration of life at successive future dates is a parabola ascending continually and with increasing speed and takes no account of any possible limit to human life. But if this parabolic law really holds, why stop, as Hart does, at the year 2000? At that time the rate of life lengthening would be, Doctor Hart finds, 80 years per century. Allowing for the same acceleration as before, within another century the average lifetime would exceed 200 years, and in a few more centuries it would exceed Methuselah's alleged record. After that we would have to measure human life in thousands of years, tens of thousands, and ultimately in millions or trillions! Even the wildest imagination must shrink from such extravagant hopes.

I think we can discuss the question best by dividing it into two:

1. If there exists a natural limit to human life of, say, 100 years, how far may we expect to increase the duration of life?

2. How far, if at all, may we extend the alleged natural limit of 100 years?

If, as has commonly been supposed, a natural life cycle exists and the extreme life span is a part of that natural life cycle, the utmost we can hope to accomplish is to eliminate deaths occurring earlier than this natural limit, which deaths for the most part may be called premature. This is merely giving each individual a fair chance to fill out his natural life span by protecting him from accidents, disease germs, and so forth.

One hundred years is, for the sake of argument, taken as this alleged natural limit because it is conservative and because it is the limit often assumed by actuaries. They point out that few authentic cases are known in which this supposed limit has been exceeded. They point out that we have reduced the mortality in the earlier ages but not in the later, and that hitherto the chief life lengthening has been of infants' lives. We have changed the shape of the survivorship curve but not its length of 100 years.

In England, in the middle of the last century, one-quarter of the people died before they were 5 years old. In the beginning of this century one-quarter died shortly before reaching 40. Using the same two dates, we find that one-half died by the age 45 in the last century and by 65 in this, while three-fourths died before the age of 70 in the last century and a little after 75 in this. Thus the advance in this third quarter of life was only a little over 5 years as against 30 or 35 years in the first quarter. The nearer we reach the century

mark the less improvement do we find. The century seems to round out man's age, which very, very seldom runs into three figures.

If we assume this 100 years as the limit, we must substitute for Hart's parabolic law of progress an entirely different type of curve the specifications for which may be: 1. That we start off at the present average duration of life in the United States, 58 years, and with the present rate of life lengthening, 4½ years per decade; 2. that this average shall approach 100 years as a limit; and 3. that its rate of increase, relatively to the possible room for improvement still left, shall be maintained at 10 per cent, or about the present rate. The figure 58 years is that shown by Dublin to represent the average in the registration area in 1921, 1922, and 1923 in the bulletins of the Metropolitan Life Insurance Co. (24). The results of such a forecast are:

Forecast of the average duration of life

Year:		Year:	
1922	58	1970	75
1930	61	1980	78
1940	65	1990	80
1950	69	2000	82
1960	72		

By the year 2100 the average duration of life would be 94 years; in another century it would be 98 years; in another, 99 years; and thereafter it would remain between 99 and 100, all the time approaching closer to the unattainable limit, 100 years.

According to this schedule the average lifetime would reach Dublin's estimated increase at about 1940, would nearly reach our committee's quota of 20 years additional within the 50 years specified, and by the year 2000 would reach the highly respectable figure of 82 years.

These results seem conservative, for certainly 100 years is a safe figure for the extreme limit of life, and a progress every decade of 10 per cent of the room for improvement left seems, on the basis of past experience, a very safe figure. We ought to have considerable confidence that we shall actually beat this schedule and become a Nation of octogenarians by the end of this century.

Before considering the second question (whether 100 years is the limit) we may dwell on how we may expect at least to keep up with the preceding schedule.

We can do this partly by nature's methods of acquiring immunity, as the negro has acquired a natural resistance to hookworm, and partly by consciously fighting germs, continuing the work begun by Pasteur, for of course the modern quickening of life extension begins with him. He said:

> It is within the power of man to rid himself of every parasitic disease.

We ought to be able to wipe the slate almost clean not only of typhus, yellow fever, and typhoid, but of diphtheria, tuberculosis, and numerous other germ diseases.

The chief difficulty is not lack of knowledge but lack of its application.

APPLICATION BEHIND SCIENCE

Dr. William H. Welch says:

> When a Koch discovers the tubercle bacilli, a Banting discovers insulin for the relief of diabetes, or a Von Behring an antitoxin for the cure of diphtheria, or a Park demonstrates the value of the toxin-antitoxin for the prevention of diphtheria, the world draws a long breath as if saying to itself, "Now we are rid of that terror which has haunted the human race for centuries." It then straightway forgets and goes on its way comfortably, assuming that of course the great discovery, or invention, is being carried into effect.
>
> The actual facts are quite different. A few people, those of unusual initiative or ample means, or who happen to be under the care of exceptionally alert physicians, or within the jurisdiction of exceptionally competent health officers, receive the benefits of the new discoveries, but the great mass of the human race goes on as before, and the death rate from these diseases is reduced slowly and over long periods of time.
>
> In fact, the health field has a woefully ineffective distribution service as compared with the laboratories of the world. We know how to do a lot of things which we do not do or do on a wretchedly small scale. Few of the great discoveries of preventive medicine, except the prevention of yellow fever, are anywhere nearly fully applied.

But we do not need to go for our illustrations to such definite discoveries as Von Behring's; even the common-sense knowledge of exercise, sleep, fresh air, and food is not yet well applied.

What science is really doing is rediscovering simple biological living. Civilization has brought bad sanitation, and now civilization, through its greatest product, science, is simply cleaning up its own mess.

The invention of window glass deprived man of the ultra-violet rays and shut out the air. The death penalty resulted through tuberculosis in millions of cases. Now we have found this out and seek sunlight, natural and artificial, and invent "vita glass" and "celo glass" to let the healthful rays in again. In such ways man has upset the equilibrium of nature and needs to find scientific ways to restore the lost equilibrium.

Dr. Eugene L. Fisk and I have assembled many illustrations (2) of the unhygienic effects of such products of civilization as housing, clothing, cooking, softening our food, and industrial conditions. The condition of civilized man's teeth compared with those in prehistoric skulls or of uncivilized tribes to-day affords an obvious illustration. Intestinal conditions afford a less well-recognized illustration.

The task of applying hygiene naturally falls under three heads: 1. Public hygiene, i. e., hygiene through governmental health agencies; 2. semipublic hygiene, i. e., hygiene through other institutions (this includes school hygiene, industrial hygiene, and the hygiene of life-insurance companies); and 3. individual hygiene, i. e., hygiene through the voluntary effort of the individual.

PERIODIC MEDICAL EXAMINATIONS

The first of these three is the particular job of the members of this association. But their task is much larger than that; it should include an interest in the other two, and especially the third.

The individual must be taught to practice individual hygiene. He can be stimulated to do so by periodic medical examinations. At the recent meeting of the American Medical Association at Dallas the president in his address stressed this more than anything else. It has been advocated occasionally for over half a century (24). Doctor Dobell (8) of England advocated it in 1860, Doctor Barès (9) of France in 1902, Dr. George M. Gould (10) advocated it in 1900. Dr. Burnside Foster advocated it in 1908 before the Association of Life Insurance Presidents, following my own address advocating life extension by life-insurance companies. All of these authorities developed the idea independently, but it was not given any wide practical application until the establishment of the Life Extension Institute in 1914, when as the outgrowth of these efforts and of the cooperation of Gen. William C. Gorgas, ex-President Taft, Dr. Eugene L. Fisk, and, most of all, Harold A. Ley, we founded the Life Extension Institute through which this ideal of periodic medical examinations has been made real. The chief objective was to harness up the profit-making motive of the life-insurance companies with the task of lengthening human life.

After six years' experience, during which the Metropolitan Life Insurance Co. used the service, its statistical department, under Doctor Dublin, cast up accounts. The results were so astonishing that the actuarial department and the medical department refused to believe them until forced to do so by going over the records for themselves. The three departments then united in a report showing that, as a consequence of expending $60,000 on medically examining 6,000 people within six years, the Metropolitan had gained, through premiums of people whose lives were extended, $120,000. In other words, this life-insurance company had made 100 per cent on its investment.

This research was carried forward by Dublin to cover a total period of nine years and showed an average reduction of 18 per

cent in the death rate of the policy holders affected and, among a group of impaired lives, a reduction of 50 per cent (11). Thus was demonstrated the power of individual hygiene even when it was, as we know, only very imperfectly applied. After this record 44 other life-insurance companies joined the service.

The Life Extension Institute has now examined 500,000 people and stimulated the custom of periodical medical examinations among the medical profession. Perhaps its most important service consists in thus stimulating physicians to pay more attention to individual hygiene (12). Any thorough examination will find defects, both in physical condition and in habits of living, among over 99 per cent of those examined. Anyone who sets out to improve his health finds plenty of room for improvement. But to help him to secure this possible improvement the medical profession needs higher standards of health. Physicians are trained to treat the sick; they must learn how to treat the so-called well.

In order to get any results, the physician who preaches hygiene must also practice what he preaches. To merely examine a man is not enough; the physician must have something educational to give, and he must take it seriously himself. The essence of improving health for the so-called well is improving habits. Habits are slow to change, yet only in this way shall we ever add greatly to the expectation of life at the later ages.

If by merely scratching the surface of individual hygiene the death rate can be reduced 18 per cent and for impaired lives 53 per cent, what may we not expect if health ideals ever really take hold of our civilization (14)?

The favorable results of the Metropolitan Life statistics confirm, and are confirmed by, the similar statistics of the Guardian Life and the Postal Life. The Guardian Life finds an average reduction of 23 per cent in the death rate of the policy holders affected. The experience of the examinees shows that many with overweight corrected it before the next examination and that even such serious symptoms as albumin and sugar in the urine were checked.

It may be thought that the life-insurance policyholders who take examinations are a self-selected group. To meet the objections, a test is being made among industrial workers, who are examined as a group (25), and where self-selection is practically absent.

Prof. A. H. Ryan (15), of Tufts Medical School, working on such data taken from the Life Extension Institute, has given exact statistical expression to the actual influence of the periodic health examination in a paper not yet published (7).

Improvement in physical condition of industrial workers resulting from periodic physical examination as revealed by the medical and surgical attention needed at three successive years of examination (596 individuals)

Class of medical or surgical attention needed	Number of cases needing attention at first examination	New cases needing attention at second examination	Percentage of cases cured within year following discovery of impairment
General medicine	90	60	69
Eye	217	66	52
Ear	64	24	58
Nose and throat	144	79	50
Surgical	79	62	62

Summarizing the facts in the table, we find that within one year of the first examination a great reduction in the apparent need for medical treatment and correction of disabilities, ranging from 50 to 69 per cent in the various classes of disability, was found, and there is no reason to doubt that these results are to be credited to the influence of periodic health examination, the counsel and suggestion based upon it, and the attentions of the family physicians to whom those needing medical treatment were referred.

Another interesting feature of Professor Ryan's study is the fact that, in an effort to ascertain the possible influence of focal infections, a study of about 8,000 examined cases showed that focal infection was so widely prevalent that it was impossible to secure a pure group of noninfected cases of a size adequate for comparison. This revelation of the extent of human impairments emphasizes the wide margin for possible improvement already stressed.

Both in England and in the United States the World War disclosed unsuspected physical shortcomings (13). General Pershing said the physical condition of a high percentage of young Americans was a disgrace to any nation (13).

It is important that these lessons should not be missed by hygienists. They seem too often to be overlooked. Even Raymond Pearl, professor of biometry at Johns Hopkins University, in a popular article in the American Mercury seems to advise his readers against periodical medical examinations and exhorts them to "live as a Christian Scientist is supposed to live, without thought or fear of disease. But *when you feel ill* [the italics are mine], consult a physician at once."

The chief trouble with advice to wait until you feel ill is that in many cases a person does not "feel ill" until long after he has become ill. Who to-day would apply such advice to dentistry: "Wait till your tooth aches; until then do not bother to visit the dentist for

examination." We all know that the time to put teeth in order is when the cavity or focal infection begins, which is long before the teeth ache. The same is true of many far more vital organs than the teeth. Long ago Metchnikoff remarked that some of the worst diseases, such as diabetes, come upon their victims unfelt. The whole modern movement to check cancer is based on early examination long before the patient begins to "feel ill." The same is true of tuberculosis, intestinal toxemia, and numerous other ailments.

One of the chief findings of the Life Extension Institute is the enormous extent of these unfelt ailments or, as Dr. Fisk calls them, "silent sickness." The same fallacy affects most sickness statistics. Such sickness statistics as in Sydenstricker's Survey (16), can take no account of unfelt illness. For this reason they show a disproportionate amount of certain types of ailments as compared with the deaths for those ailments.

HABITS SLOW TO CHANGE

But the real obstacle to individual hygiene is the slowness of custom and habit to change. Experience with prohibition has shown that old habits and customs die hard, even when we set out to kill them by law and know they ought to be killed.

In the case of lesser evils than alcohol, such as tobacco, tea, coffee, excessive meat eating, neglect of exercise, or of water drinking, or of elimination of body wastes, the scant use of sunlight and fresh air, the mental burdens of worry, phobias and manias, the difficulty of waking up the public is enormous. Many of us who have had tuberculosis are more than willing, for ourselves, to give up smoking, coffee drinking, and other indulgences, and find that to give them up is not a sacrifice but an emancipation. But when we propose that the average man shall do likewise we usually find that he can not be stimulated to do so except, to a very minor degree, through periodical medical examinations. Probably it is only in this slow way that our health ideals will gradually be elevated very far. When that time comes, most of us can approximate the limit of 100 years which has been discussed.

CAN WE EXCEED 100 YEARS?

Dare we go any further? Certainly yes, if we can see our way clear to pushing forward that 100-year limit, or alleged limit. But can this be done? Past experience, it is true, gives us little hope. There seems to be a fatal fascination about that round figure, the century mark. One actuary, formerly president of the American Actuarial Society, said that he saw no prospect whatever that this apparently fixed barrier would ever budge. T. E. Young, one time

president of the British Institute of Actuaries, reached similar conclusions. In his book On Centenarians (17), he found only 22 indisputable examples of centenarians with ages ranging to upwards of 105, although in a later edition he was able to increase the number to 30 and the limit to 111.

Most alleged cases are simply exaggerations, or errors. For instance, the Countess of Desmond is said to have lived 140 years, owing to a confusion of two persons of the same name, an earlier and a later countess. The 140 years was apparently the interval between the birth of the earlier and the death of the later.

Dublin, in his conservative forecast, does not allow for any improvement in mortality after the age of 70 years. In England, in the middle of the eighteenth century, the expectation of life after the age of 45 was rather better than to-day. Halley's life table for 1687–1691 showed an expectation of life after age 80 greater than to-day's although, as Pearl (18) points out, the data are too scanty to make the result significant.

In ancient Egypt, 2,000 years ago, according to Karl Pearson, though the average life lasted only 30 years, after about age 68 the expectation of life was greater than ours, owing presumably to natural selection.

When confronted with these stubborn facts we must confess that the problem of extending the limit of human life beyond 100 years is not an easy one. But I believe the 100-year limit is a bogey which can, and some day will, be beaten.

There are five lines of evidence which, taken together, seem to be fairly conclusive that the possible life span of man is much more than the century which life-insurance experience seems to indicate.

WHAT ACTUARIAL SCIENCE INDICATES

The first line of evidence is derived from the very tables on which actuaries rely, although it seems never to have been noted. If we examine the "force of mortality" year by year, we find that after the age of 60 years, while this mortality continues to increase, its *rate* of increase does not. Instead it remains almost exactly constant until the age of 85, after which it actually decreases, especially for females. Figure 4 shows this.

The studies of Westergaard for centenarians confirms this slowing down of the acceleration. He even found (20) in Norway that while nonogenarians had one chance in three of dying within a year, centenarians had only one chance in four. Now, if there exists any definite limit to human life the situation ought to be the reverse. The force of mortality ought to grow heavier and heavier and the curve representing it ought to bend, not toward the horizontal, but toward

the vertical, approaching an impassable barrier or "asymptote." On the basis, therefore, of the only statistical evidence we possess we find absolutely no hint of any definite limit to human life. On the contrary, the right-hand end of the curve hints the exact opposite.

It is dangerous to extrapolate any statistical curve, for there is no telling which way it will turn; but if we assume that the mortality of centenarians is not over 50 per cent per annum, which is conservative so far as our scanty facts go, we would have at least one centenarian out of a thousand reaching 110 years, and of those who reach 110, one out of a thousand reaching 120, and so on indefinitely. There

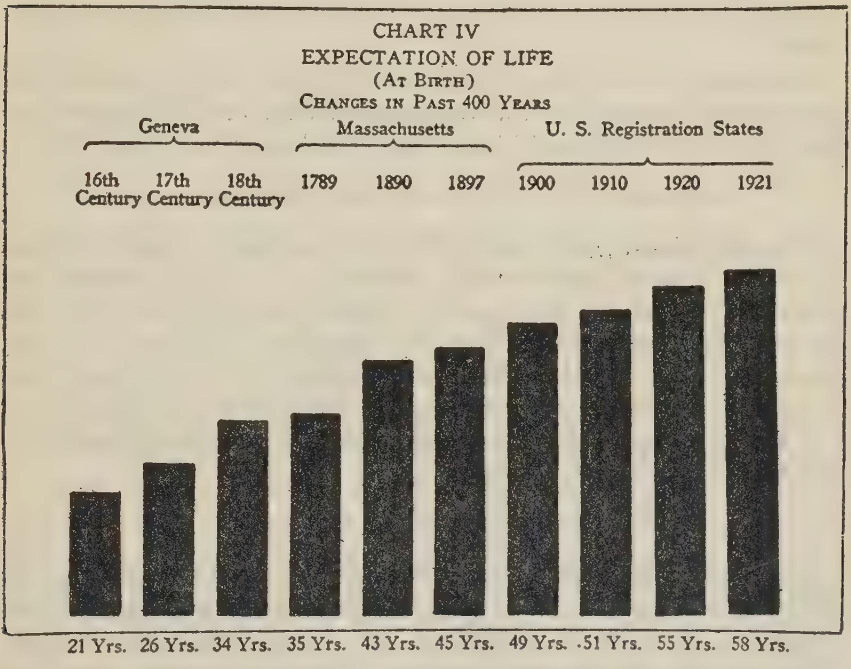

FIG. 4.—Most of the gain due to improvement in death rates under age 45

would be one to reach 140 out of a trillion centenarians and one person would reach 180 out a trillion trillion centenarians. Such a "law" of mortality does not seem unreasonable. Whether the chance of reaching 180 under this law is greater or less than the proverbial chance that a blindfolded man could write Hamlet by setting type picked out by random, I do not know. I am not stressing the practical importance of such slim chances.

What I am stressing is that we must apparently give up the concept of any definite life span and substitute the concept merely of

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chance of survivorship, which diminishes indefinitely, but with no known or knowable limit. At any rate, this, and not a natural life span, is the lesson of acturial science.

DELETERIOUS INFLUENCES REMOVED

The second line of evidence is that centenarians, like the rest of us, are invariably exposed to life-shortening influences. The removal of these influences ought therefore to lengthen their lives just as it lengthens others. I, myself, have collected 170 life histories of the very aged. On the average they lived much more hygienically than most people. But few of them were such paragons of virtue as Carnaro, while all of course had to battle with bacteria to some extent.

It stands to reason that if they had enjoyed a germ-free environment or had lived up to the very highest standards of hygiene, or both, that their lives would have been even longer than they were.

MORTALITY RATES DIMINISHING IN UPPER AGES

The third reason for thinking 100 years too small a limit is: Recent experience clearly indicates that, contrary to prior experience, the mortality rates are beginning to diminish even at the upper age groups. The American actuary just referred to admitted this and reminded me that I had predicted it in talking with him 20 years ago. Even at that time the same phenomenon had appeared in Sweden.

It stands to reason that the causes which are diminishing mortality at the higher ages will continue.

AUTHENTIC CASES OF LONG LIFE

The fourth reason for believing the 100-year limit too small is that life-insurance experience and, still more, the larger experience of the census and of special investigators, like Westergaard, find a considerable number of apparently authentic cases of people who have lived 105 or even 110 years, and occasionally 120.

In Portland, Oreg., Mrs. Mary L. Wood died at the age of 120 years and under circumstances which permitted the authentication of her case by the Oregon Historical Society.

The extremest case with any good claim to authenticity is that, studied and accepted by Westergaard (20), of the Norwegian Drakenberg who was born in 1626 and lived until 1772, aged 146.

He was married when 111 years old, and as a widower of 130 proposed to marry again, although without success.

It stands to reason that if a few people have actually passed the age of 120, in the future many more may do so.

LIFE CELLS IMMORTAL

The fifth reason for suspecting that our previous notions of a life limit are wrong is that modern biology finds the life cells and many tissues potentially immortal. This is perhaps the most sensational conclusion which science has ever reached. Yet, according to Pearl in his excellent book, The Biology of Death (18), Loeb and Carrel and others have demonstrated its truth beyond reasonable doubt.

NO NATURAL DEATH FOUND

Woodruff, of Yale, found no natural death in a culture of *Paramecium* in 8,500 generations, equal to 250,000 years of human life, and the culture was going as well at the end as at the beginning. Morgan, of Columbia, found 1/250 of a worm (*P. maculata*) will regenerate and be "younger" than the original. Carrel has kept the cells of a chicken embryo's heart alive for many years by washing out the poisons generated in the life process and protecting against infection and food deficiency.

All of these studies are wonderfully suggestive for the future, although they are for the present far beyond the range of any practical application.

It would seem that biologists are gradually surrendering the idea of any natural death, or life span (19), and reaching instead the idea that all death is accidental.

This change of view, if it comes about, will be revolutionary. Hitherto we have taken for granted a natural cycle of life with its various phases located at more or less definite intervals—birth, puberty, maturity, climacteric in females, and death—all spaced in a due relationship to each other. But when we attempt to put it in figures we find far less indication of a natural age for death than of the other milestones in life, such as puberty, for instance. The age of puberty varies but little in any one species and the variation from the mode follows the usual frequency distribution. If mortality followed such a law, it would center about some mode such as threescore years and ten. But it does not do so very definitely.

Even Pearson, the greatest apostle of chance in biology, could find no such law except by superposing (21) five frequency distributions, and Pearl (18), who, if anyone, should be sympathetic with Pearson's point of view, regards this as an artificial fitting of curves and not the interpretation of any fundamental biological tendencies. The frequency curve is realized to some extent for individual diseases and disease groups, as Arne Fisher has emphasized.

Metchnikoff (22) assumed that while to-day all deaths are accidental, whether due to the invasion of a bullet, a poison, or a germ, if we could safeguard against these we should reach a natural death at, say, 125 years of age.

INDEFINITE EXTENSION OF LIFE

But the present tendency is in the direction of assuming that all deaths are, always were, and always will be accidental in nature and that by safeguarding against bullets, poisons, and germs we can theoretically extend life indefinitely. The picture we seem gradually to be forming is not the old picture of a life cycle, which includes death, but rather of a cycle ending in maturity (or, at most, the climacteric in women), just as the processes of making a watch end in its completion. After completion the body may last until some one of its millions of parts suffers sufficient accidental injury to stop the whole machine, just as a watch may stop from a breaking of the mainspring or a clogging with dirt. If this be the true picture, there is no normal natural lifetime for man any more than there is a normal lifetime for a watch. It is all a matter of having the man or watch well built to start with and well taken care of afterwards.

It may be that a superhygiene, a gland transplantation, or other device or devices yet unknown will some day open up these new vistas so that man may enter and take possession. The only obstacle seems to be his highly differentiated structure. There are so many parts to get out of order, the failure of any one of which reacts to cause the failure of all—that is death.

EUGENICS

But the lesson of this is that, with such a complicated and interdependent assemblage of organs, man's only chance of great longevity is to keep every single part of his machinery close to a 100 per cent efficiency. This can only be done by hygiene carried to the *n*th power as well as by eugenics or "race hygiene."

Ordinary hygiene unaided by eugenics may break down; that is, ordinary hygiene is good for this generation, but threatens to be bad for succeeding generations by prolonging the lives of the unfit. And birth control, which some day may operate eugenically, is now operating dysgenically. The ultimate hope of mankind lies in eugenics. Alexander Graham Bell hoped the time would come when young men and girls who could boast of inherited longevity would be especially sought in marriage. Karl Pearson and Miss Beeton showed that inheritance does influence longevity. Alexander Graham Bell found that the average age at death of those whose parents both reached 80 was 52.7, while the average age of those whose parents died below the age of 60 was 32.8.

As Raymond Pearl (18) and Dr. Mazÿck P. Ravenel (23) say, in discussing this study of Bell's, the longevity of the parents of the first group added 20 years to their life as compared with the second group.

They contrast this with my own estimate in 1909 of what hygiene can accomplish and maintain that eugenics is much more important than hygiene as a means of lengthening the life of the race.

But changes in marriage selection can only slowly influence the length of human life. It can only operate generation by generation and is therefore a matter for future centuries. Meanwhile it is good to know that we can greatly help ourselves in our own generation through hygiene, and, as Stephen Smith said, "send messengers of hope in a new scientific standard of long life." We may also be spurred to try to emulate his own splendid example of living long and living right.

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CHARLES DOOLITTLE WALCOTT, 1850-1927

Fourth Secretary of the Smithsonian Institution

CHARLES DOOLITTLE WALCOTT[1]

By George Otis Smith

[With 2 plates]

Leadership is not an accident; the position of Charles Doolittle Walcott among his fellow scientists is subject to scientific analysis, just as the characters of a Cambrian type organism justify study from the viewpoint of phylogeny and ontogeny. Ancestry and environment, as well as self-determination, explain the truly successful life of high scientific attainments, valued public service, and winning personality that made the late Secretary of the Smithsonian a leader in American science.

The future scientist's interest was early stimulated by his environment. He was born in New York Mills, Oneida County, N. Y., March 31, 1850. At 7 years of age he was already a collector of the natural objects that attract the attention of the country boy, and at 13 the curiosity aroused by some fossils he found started him on the way to the study of local geology, which later opened up the larger questions of evolution of life on the earth and of the origin of the earth and the solar system.

Of this period he says, referring to fossils accidentally opened up by his wagon wheel when driving:

> In a small drift block of sandstone which I found in 1867 on the road from Trenton to Trenton Falls, Oneida County, N. Y., there is an unusual apparent association of Upper Cambrian and Ordovician fossils. When as a boy I found the rounded block of sandstone referred to, I broke out all the fossils possible, as at the time I was well acquainted with the Trenton limestone fauna, and the fossils in the block were strangers to me, with the exception of *Leperditia armata.* The following winter I endeavored to locate the stratigraphic position of the associated trilobites but could not, further than that they were evidently of pre-Trenton age. This study aroused an interest in the American early Paleozoic fossils that gradually led me to take up the Cambrian rocks and faunas as my special field of research.

A college education was not granted to young Walcott. His paternal grandfather had endowed a professorship at Hamilton College, and his father had held a leading place in the community but died

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when Charles was only 2 years old. To his training in the public schools and the Utica Academy he added reading and study along lines of his own choice. His later associates have shared with him his own doubt whether a collegiate course would have replaced the training in initiative and continuity of purpose with which seemingly adverse circumstances endowed him.

At 23 he planned to study at Harvard under Louis Agassiz, but the great teacher's death a few months later shut that door of opportunity. Yet his own testimony is that the influence of Agassiz served as an abiding inspiration in keeping his purpose steadfast. The memoir appearing in 1918 summarizing the results of a research of 45 years on the appendages of trilobites was the fulfillment of a promise made to Louis Agassiz in 1873.

In 1876 came his first professional appointment, as an assistant to James Hall, State geologist of New York, and three years later he joined the newly organized United States Geological Survey as assistant geologist. In 1882 he collaborated with Arnold Hague in the survey of the Eureka mining district in Nevada and the working out of the great Paleozoic section of central Nevada. The charge of the Paleozoic paleontology of the survey was now assigned to him, and though this entailed considerable routine work in the identification of fossils brought from many fields by the various geologists, he was enabled to pursue with vigor his cherished plans for the investigation of the older faunas. He examined the Cambrian formations of the Appalachian belt all the way from Alabama to Quebec and carried his researches on a more easterly line through New England and New Brunswick to Newfoundland. He also began a series of western studies which eventually included the most important known bodies of Cambrian and pre-Cambrian rocks in Texas, Arizona, California, Idaho, Nevada, Montana, Wyoming, and South Dakota.

In 1888 he visited Wales for the purpose of making a personal study of the type district of the Cambrian system—the district rendered classic by the original labors of Sedgwick and the subsequent researches of Hicks. It was on this visit to England that he presented his Cambrian researches before the International Geological Congress at London.

Of his work as a student of the Cambrian and Algonkian sedimentary formations and included organic remains he says:

> My own investigations have been mainly in the Cambrian and pre-Cambrian strata and have involved new and somewhat startling discoveries that helped to show how very much earlier life was developed on our planet than we had previously supposed. These researches have taken into consideration the records left on all the continents and many of the great islands. Field work, with compass, hammer, and chisel, has been the rule, followed by laboratory

and critical comparison of many thousands of specimens of fossil genera and species of ancient marine life, and often study of microscopic sections of rocks and fossils in the hope of finding evidence of the presence of minute and active bacterial and simple algal workers, such as exist in modern seas and lakes, which by their united efforts form great masses of the recent sea and lake deposits.

These researches in Cambrian geology and paleontology, which were continued until his death, constitute his outstanding contribution to science and won for him from foreign and American societies five medals, including the Wollaston medal, the highest honor at the disposal of the Geological Society of London. One of his fellow scientists recently estimated that of the sum of existing knowledge on those subjects 70 per cent had been contributed by Doctor Walcott and that fully half of his work in this field was done within the last 20 years—a record truly remarkable in view of his diverse activities and responsibilities.

His powers of specialization and generalization were equally well developed; he discerned every minutest feature of the organisms on which he worked, but he was also able "to think in continents," and so his studies made large contributions toward unraveling the problems of Paleozoic physiography.

A scientist by deliberate choice and highly successful in his chosen field, Doctor Walcott allowed no talent to remain unused. He had the mind of a skilled executive with exceptionally sound business sense and of a successful diplomat with marked ability in coordinating policies and uniting men. Although at the age of 21 his proved capacity invited a business career and later much more promising opportunities came to him, his obvious genius for business was turned into channels of public service.

The simple title of his address as retiring president of the American Association for the Advancement of Science in 1924, "Science and service," concisely stated his creed; advancement of science implies "the physical, mental, and moral advancement of the human race," and in his public life this research scientist so applied his talents that his public service perhaps overshadowed his science.

Exceptional capacity for the dual duties of research and administration eminently fitted Doctor Walcott for the two official positions he held during the third of a century in which he was a prominent figure in public life. As Director of the United States Geological Survey, 1894–1907, he so administered that scientific bureau, devoted to fact finding and the coordination of facts and principles, as to serve both the Government and the people. "The public" as defined and served by Director Walcott included farmer, miner, landowner, and investor as well as student, teacher, and research specialist. He was prompt to see the need of research, both scientific and engineer-

Secretary Walcott was a member of the council and vice president of the National Academy of Sciences, and from 1917 to 1923 he was its president, an honor earned by his scientific attainments and an opportunity for leadership during a critical period that called for administrative skill. It was in no small degree due to his guidance that organized science received so large a meed of credit for its patriotic service. The beautiful home of the National Academy and Research Council also embodies much of Doctor Walcott's genius in planning and execution.

Academic honors that came with the years included the degree of Sc. D. from Cambridge and Harvard Universities; LL. D. from Hamilton, Chicago, Johns Hopkins, Pennsylvania, Yale, St. Andrews, and Pittsburgh Universities; Ph. D. from Royal Frederiks University, Christiania, and the University of the State of New York; and doctor honoris causa from the University of Paris. Doctor Walcott held membership in the leading foreign scientific societies as well as those at home, and he was foreign associate of the Académie des Sciences of the Institut de France.

The man behind the career is what counts, after all, and as a man Charles Doolittle Walcott was never found wanting. He was not only a scientist among scientists but a man among men. His was a noble record of genial, sympathetic, and encouraging contact with his fellows. He made and kept friends. Many are the tributes of affection for the man and testimonials of indebtedness for his helpful and inspiring fellowship and friendship, a rich heritage that proves how well he invested his years. The Walcott home was both the place of quiet and happy family life and a center of influence among scientists and public men. Great sorrow came in the death of his wife Helena Stevens Walcott, and later of two of their sons, but he continued to face life with the same calm, steadfast, and optimistic spirit and met his multifold duties without any respite.

Truly, Doctor Walcott looked to the hills for strength. His extensive researches after he became Secretary of the Smithsonian Institution were carried on largely in the magnificent mountain country of British Columbia and Alberta, which he called a "geologist's paradise." And as a writer in the Geological Magazine (London) remarked:

> Doctor Walcott has already admitted others to his paradise by the publication of the beautiful photographs and photographic panoramas of the British Columbia Alps, which bear testimony to his skill as an expert photographer of mountain scenery.

In the later excursions to the mountains the geologist's interest in their beauty was augmented by the artistic studies of their flora by his wife Mary Vaux Walcott, who shared with him every interest, scientific and public.

DOCTOR WALCOTT OPERATING CIRKUT-CAMERA ON SOUTH SLOPE OF THE SAWBACK RANGE, LOOKING ACROSS BOW VALLEY, ALBERTA, CANADA, DURING HIS GEOLOGICAL FIELD WORK IN THE SUMMER OF 1919

(Photograph by Mrs. C. D. Walcott, 1919)

Charles Doolittle Walcott was a man of faith—faith in his science, faith in his fellow man, and faith in God and the future life. He was outspoken as a churchman—in his own words, "an active church worker," and as described by a fellow scientist, "a man of deep religious conviction," one of a group of notable scientists who published their simple confession of faith that there is no conflict between science and religion.

As was said by the editor of the Outlook, commenting on the breadth of Secretary Walcott's interests, scientific, civic, and artistic:

> He was a man of spiritual insight, and though he knew as a scientist how to weigh and measure he valued most highly those things that are measureless and imponderable.

WILLIAM HEALEY DALL, 1845-1927

WILLIAM HEALEY DALL [1]

By C. Hart Merriam

[With 1 plate]

The death of Doctor Dall on March 27, 1927, removes one of the last pillars from the fast disappearing class of systematic naturalists, a class whose roll of honor in America is adorned by the names of Audubon, Agassiz, Allen, Baird, Cassin, Cope, Coues, Dana, Gill, Hyatt, Kennicott, Leidy, Newberry, Packard, Richardson (Sir John), and Verrill. And it may be said with truth that in his chosen field no one of these labored more faithfully or contributed more substantially to the advance of knowledge.

While Dall was primarily a conchologist, his interests were by no means confined to this specialty but reached out into many and divergent paths of scientific investigation. He was a student of nature in a broad sense—a naturalist in the full meaning of the term.

His early enthusiasm in the study of birds indicates the loss to ornithology when other work called him, for not only did he give us the first "List of Birds of Alaska" (1869), but his "Avifauna of the Aleutian Islands" (1873) still remains the authoritative source of published information on that extensive and then little known region. Similarly, his "Food Fishes of Alaska" (1871), his "List of the Mammals of Alaska, with discussion of the Fur-bearing Animals" (1870), "Parasites of Cetaceans" (1872), and critical studies of the Cetacea, with descriptions of new species (1873--1874), were marked contributions to the zoology of the time. His "Meteorology of Alaska" (1879) is a noteworthy volume, containing not only an elaborate summary of what was then known on the subject, but also maps showing the northern limit of tree growth and the distribution of plants and animals.

But the scope of his activities is by no means covered by the above enumeration, for, in addition to his monumental contributions to conchology, his publications enrich several other lines of research, notably anthropology, geography, tidal currents, geology, and paleontology. Still other essays of which special mention should

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be made are those on evolution, on the geographic distribution of marine animals and on "Zoological Nomenclature," the latter a painstaking and much needed work of timely service to systematic naturalists. And besides these, Dall was the author of a number of monographic volumes and a multitude of lesser papers, chiefly on the Mollusca, and also of an appreciative biography of Spencer F. Baird, a volume of more than 450 pages, published in 1915. To one unacquainted with his indefatigable industry, the number, magnitude, and quality of his published contributions to science are quite overpowering.

Dall, in common with most naturalists, developed an interest in natural history when so young that he was unable to recall the date. The accident that led him to become interested in shells was, he said, the possession when a boy of 12 of a copy of Doctor Gould's "Invertebrata of Massachusetts." Inspired by this work, and living near Boston, he undertook to make a complete collection of the shells of Massachusetts. Finding species that he was unable to name, he made bold to consult the author, Doctor Gould, who gave him much sound advice, and whom Dall characterized as "one of the best and most lovable of men."

A little later, when employed in an office on the India wharf in Boston, where he did boy's work for wages, he kept a book in his desk and at odd times when unoccupied with his regular task copied scientific books which he then thought he would never be able to buy.

The next factor in shaping his zoological career was work in the museum at Cambridge, where he fell under the magnetic influence of Louis Agassiz. His third opportunity occurred in Chicago at the time of the Civil War, when, having failed to obtain a livelihood in Boston, he found employment in the Windy City. Although hard at work during the day, he spent his evenings studying at the Chicago Academy of Sciences.

It was there that he met William Stimpson and Robert Kennicott, both of whom became dear personal friends. It was there also that he determined, in the event of a choice of occupations, to accept irrespective of pay the one that promised most in the way of opportunity for continuing scientific studies. Acting on this resolve, he more than once declined offers of higher salary and undertook harder work with less pay where there were better advantages for study.

In 1865 he visited Alaska as one of the scientific staff of the Western Union International Telegraph Expedition, and when his friend, Robert Kennicott, leader of the expedition, died on the ice of the Yukon, Dall, though only 21 years old, was unanimously chosen to succeed him. In 1867 he explored and mapped the mighty

Yukon River from the coast up to Fort Yukon, then believed to be on or near the international boundary. On his return he published an illustrated volume on "Alaska and its Resources" (1870), comprising upwards of 600 pages and a map, which for many years remained the standard authority on the territory. Professor Baird, appreciating his industry and talent, promptly took him into the fold of the Smithsonian Institution, which, except during absences on field expeditions, continued to be his headquarters until his recent fatal illness.

From 1871 to 1874 Dall was captain of a Coast Survey vessel and head of a scientific survey of the Aleutian Islands and adjacent coasts, the results of which, with much other material, were embodied in a quarto volume entitled the "Pacific Coast Pilot, Coasts and Islands of Alaska" (1879), prepared jointly by himself and his associate, Marcus Baker. The bibliography by Marcus Baker which accompanied it contains upwards of 90 titles of articles by Dall published prior to the year 1879.

From 1880 till his death he was an honorary curator in the National Museum; from 1884 to 1925 he was paleontologist of the United States Geological Survey; from 1893 till 1927 he held the chair of invertebrate paleontology in the Wagner Institute of Science; and from 1899 to 1915 was honorary curator of the Bishop Museum, Hawaii.

He was the recipient of several medals and honorary degrees, including that of LL. D.

In 1899 Dall was one of the most eminent of the scientific guests of the late E. H. Harriman on the famous and unique Harriman Alaska Expedition. It is well within the truth to say that in view of the vast amount of work done by Dall during his 13 previous visits to Alaska and in the preparation of his publications on the geography, geology, meteorology, anthropology, and natural history of the territory, his knowledge was of the greatest service, while his genial disposition and readiness to answer multitudes of questions, both to individual members and at the evening gatherings in the cabin, made him the most beloved member of the expedition. To the series of 13 volumes on the results of the research work of the voyage, he contributed a valued article on the "Discovery and Exploration of Alaska" and a beautiful and touching poem on the Innuit People.

Like Baird, under whose kindly influence many years of his life were spent, his mind was a treasure house of information in various fields of science, geography, exploration, and other subjects, and although one of the busiest men in the world he gladly gave the benefit of his wide knowledge to earnest seekers for truth. To young

men and women who had chosen some branch of zoology or kindred science for their life work he was always willing to lend a helping hand and was always patient, kind, helpful, and generous.

His own views as to the attributes and qualities that go to make up a naturalist were expressed in an address on "Some American Conchologists," delivered in Washington more than 40 years ago, in which he states:

> The only lesson which may be said to be absolutely clear is that naturalists are born, and not made; that the sacred fire can not be extinguished by poverty nor lighted from a college taper; that the men whose work is now classical, and whose devotion it is our privilege to honor, owed less to education in any sense than they did to self-denial, steadfastness, energy, a passion for seeking out the truth, and an innate love of nature. These are the qualities which enabled them to gather fruit of the tree of knowledge.

And it is obvious from the character of his own work that he believed that "what is worth doing is worth doing well."

My acquaintance with Dall dates back more than half a century, for it began in 1875 in the laboratory of the United States Fish Commission at Woods Hole, a favorite meeting place for scientific men, then under the capable and friendly management of Professor Baird. Professor Verrill was in charge of the invertebrate studies, while among the laboratory assistants were Sidney I. Smith, Samuel F. Clarke, E. B. Wilson (then a mere lad), Tarleton H. Bean, and myself. William H. Dall, Alpheus Hyatt, and David Starr Jordan were among the many who visited the laboratory or worked there for short periods.

It was the possession of such sterling qualities as intellectual capacity, patience, industry and thirst for knowledge, coupled with high ideals of integrity and obligation, that enabled Dall to attain the position he so long held among the eminent scientists of the world. The closing words of his appreciation of his friend William Stimpson may well be applied to himself:

> Those who had the privilege of his companionship will carry an abiding memory of his abilities as a naturalist and his noble and lovable characteristics as a man.

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